



# The Brain's Response to Drugs Teacher's Guide

— Revision —

**NIDA**  
NATIONAL INSTITUTE  
ON DRUG ABUSE



*Come Lead  
My  
Exploration  
Team*







# Mind Over Matter



## TEACHER'S GUIDE

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U.S. Department of Health and Human Services  
National Institutes of Health  
National Institute on Drug Abuse  
Office of Science Policy and Communications  
Science Policy Branch  
6001 Executive Boulevard, Room 5230 MSC 9591  
Bethesda, Maryland 20892



## "MIND OVER MATTER" TEACHER'S GUIDE

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# Introduction



## "MIND OVER MATTER" TEACHER'S GUIDE

This is the teacher's guide for the "Mind Over Matter" series. This exciting neuroscience education series, developed by the National Institute on Drug Abuse (NIDA), a component of the National Institutes of Health, is designed to encourage youngsters in grades 5-9 to learn about the biological effects of drug abuse on the body and the brain.

The "Mind Over Matter" series includes eight colorful, glossy magazines, each of which is devoted to a specific drug or drug group; including stimulants, hallucinogens, inhalants, marijuana, opiates, nicotine, methamphetamine, and steroids. Each of the magazines describes the effects of specific drugs or drug types on the anatomy and physiology of the brain and the body. These educational materials further elaborate on the way in which these drug-induced changes affect both behaviors and emotions.

The background information and lesson plans contained in this guide, when used in combination with the magazines in the series, will promote an understanding of the physical reality of drug use, as well as curiosity about neuroscience. The guide suggests a brain anatomy educational activity that can be used throughout the curriculum (see page 43), as well as additional activities for each of the six drug topics. Of course, you are encouraged to develop your own relevant lesson plans.

**Note:** Full-size versions of Figures 1-7 are located in the back of this guide.

# Background

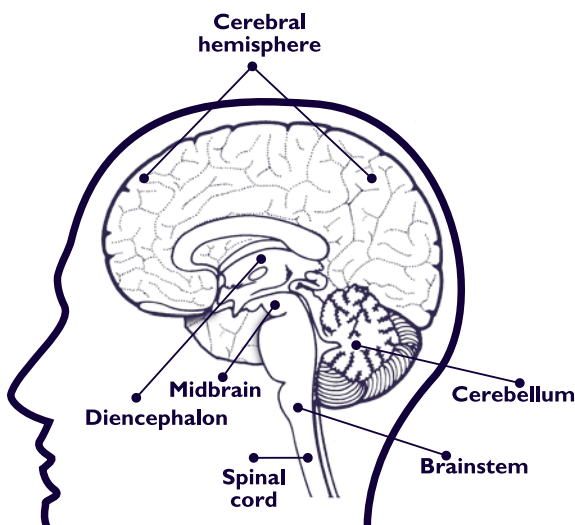
## BRAIN ANATOMY

The brain consists of several large regions, each responsible for some of the activities vital for living. These include the brainstem, cerebellum, limbic system, diencephalon, and cerebral cortex (Figures 1 and 2).

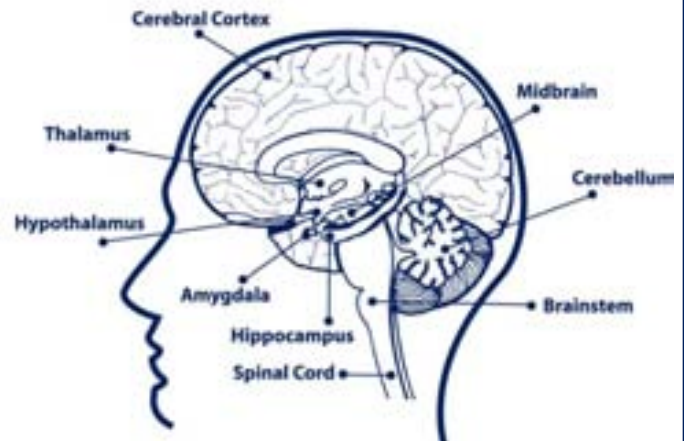
The brainstem is the part of the brain that connects the brain and the spinal cord. It controls many basic functions, such as heart rate, breathing, eating, and sleeping. The brainstem accomplishes this by directing the spinal cord, other parts of the brain, and the body to do what is necessary to maintain these basic functions.

The cerebellum, which represents only one-eighth of the total weight of the human brain, coordinates the brain's instructions for skilled repetitive movements and for maintaining balance and posture. It is a prominent structure located above the brainstem.

On top of the brainstem and buried under the cortex, there is a set of more evolutionarily primitive brain structures called the limbic system (e.g., amygdala and hippocampus, as in Figure 2). The limbic system structures are involved in many of



**FIGURE 1** This drawing of a brain cut in half demonstrates some of the major regions of the brain.



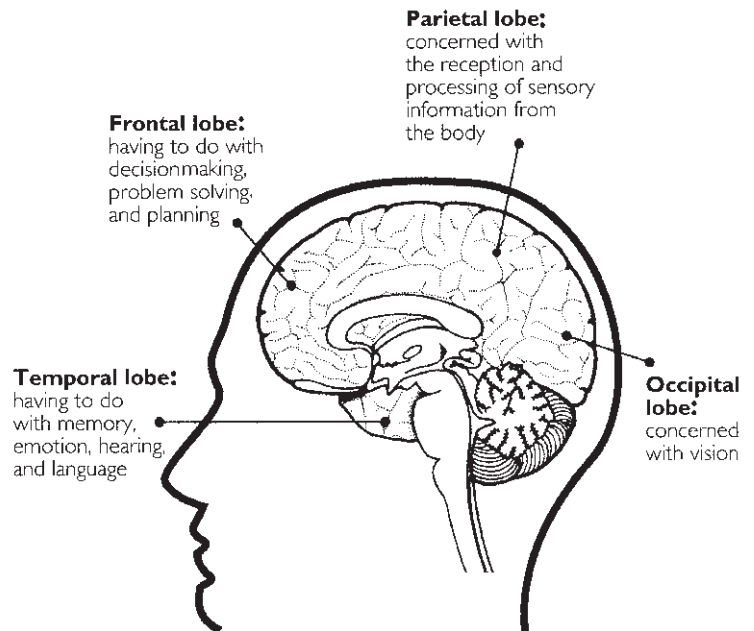
**FIGURE 2** This drawing of a brain cut in half demonstrates some of the brain's internal structures. The amygdala and hippocampus are actually located deep within the brain, but are shown as an overlay in the approximate areas that they are located.

our emotions and motivations, particularly those that are related to survival, such as fear, anger, and sexual behavior. The limbic system is also involved in feelings of pleasure that are related to our survival, such as those experienced from eating and sex. The large limbic system structure, the hippocampus, is also involved in memory. One of the reasons that drugs of abuse can exert such powerful control over our behavior is that they act directly on the more evolutionarily primitive brainstem and limbic system structures, which can override the cortex in controlling our behavior. In effect, they eliminate the most human part of our brain from its role in controlling our behavior.

The diencephalon, which is also located beneath the cerebral hemispheres, contains the thalamus and hypothalamus (Figure 2). The thalamus is involved in sensory perception and regulation of motor functions (i.e., movement). It connects areas of the cerebral cortex that are involved in sensory perception and movement with other parts of the brain and spinal cord that also have a role in sensation and movement. The hypothalamus

is a very small but important component of the diencephalon. It plays a major role in regulating feeding hormones, the pituitary gland, body temperature, the adrenal glands, and many other vital activities.

The cerebral cortex, which is divided into right and left hemispheres, encompasses about two-thirds of the human brain mass and lies over and around most of the remaining structures of the brain. It is the most highly developed part of the human brain and is responsible for thinking, perceiving, and producing and understanding language. It is also the most recent structure in the history of brain evolution. The cerebral cortex can be divided into areas that each have a specific function (Figure 3). For example, there are specific areas involved in vision, hearing, touch, movement, and smell. Other areas are critical for thinking and reasoning. Although many functions, such as touch,



**FIGURE 3** This drawing of a brain cut in half demonstrates the lobes of the cerebral cortex and their functions.

are found in both the right and left cerebral hemispheres, some functions are found in only one cerebral hemisphere. For example, in most people, language abilities are found in the left hemisphere.

## NERVE CELLS AND NEUROTRANSMISSION

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The brain is made up of billions of nerve cells, also known as neurons. Typically, a neuron contains three important parts (Figure 4): a central cell body that directs all activities of the neuron; dendrites, short fibers that receive messages from other neurons and relay them to the cell body; and an axon, a long single fiber that transmits messages from the cell body to the dendrites of other neurons or to body tissues, such as muscles. Although most neurons contain all of the three parts, there is a wide range of diversity in the shapes and sizes of neurons as well as their axons and dendrites.

The transfer of a message from the axon of one nerve cell to the dendrites of another is known as neurotransmission. Although axons and dendrites are located extremely close to each other, the transmission of a message from an axon to a dendrite does not occur through

direct contact. Instead, communication between nerve cells occurs mainly through the release of chemical substances into the space between the axon and dendrites (Figure 5). This space is known as the synapse. When neurons communicate, a message, traveling as an electrical impulse, moves down an axon and toward the synapse. There it triggers the release of molecules called neurotransmitters from the axon into the synapse. The neurotransmitters then diffuse across the synapse and bind to special molecules, called receptors, that are located within the cell membranes of the dendrites of the adjacent nerve cell. This, in turn, stimulates or inhibits an electrical response in the receiving neuron's dendrites. Thus, the neurotransmitters act as chemical messengers, carrying information from one neuron to another.



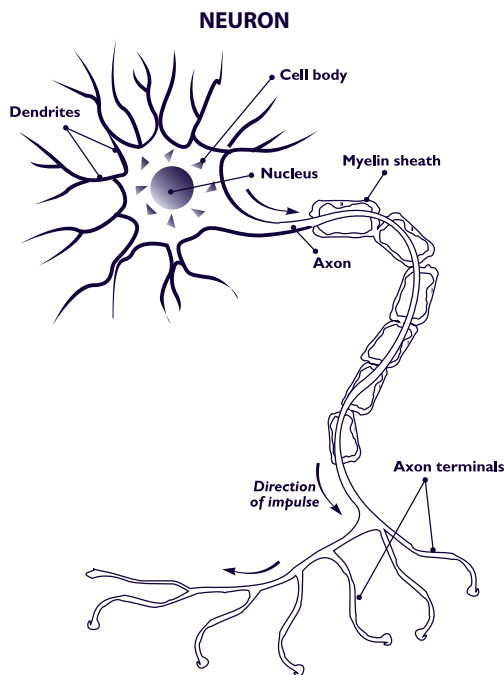


FIGURE 4

There are many different types of neurotransmitters, each of which has a precise role to play in the functioning of the brain. Generally, each neurotransmitter can only bind to a very specific matching receptor. Therefore, when a neurotransmitter couples to a receptor, it is like fitting a key into a lock. This coupling then starts a whole cascade of events at both the surface of the dendrite of the receiving nerve cell and inside the cell. In this manner, the message carried by the neurotransmitter is received and processed by the receiving nerve cell. Once this has occurred, the neurotransmitter is inactivated in one of two ways. It is either broken down by an enzyme or reabsorbed back into the nerve cell that released it. The reabsorption (also known as re-uptake) is accomplished by what are known as transporter molecules (Figure 5). Transporter molecules reside in the cell membranes of the axons that release the neurotransmitters. They pick up specific neurotransmitters from the synapse and carry them back across the cell membrane and into the axon. The neurotransmitters are then available for reuse at a later time.

As noted above, messages that are received by dendrites are relayed to the cell body and then to the axon. The axons then transmit the messages, which are in the form of electrical impulses, to other neurons or body tissues. The axons of many neurons are covered in a fatty substance known as myelin. Myelin has several functions. One of its most important is to increase the rate at which nerve impulses travel along the axon. The rate of conduction of a nerve impulse along a heavily myelinated axon can be as fast as 120 meters/second. In contrast, a nerve impulse can travel no faster than about 2 meters/second along an axon without myelin. The thickness of the myelin covering on an axon is closely linked to the function of that axon. For example, axons that travel a long distance, such as those that extend from the spinal cord to the foot, generally contain a thick myelin covering to facilitate faster transmission of the nerve impulse. (Note: The axons that transmit messages from the brain or spinal cord to muscles and other body tissues are what make up the nerves of the human body. Most of these axons contain a thick covering of myelin, which accounts for the whitish appearance of nerves.)

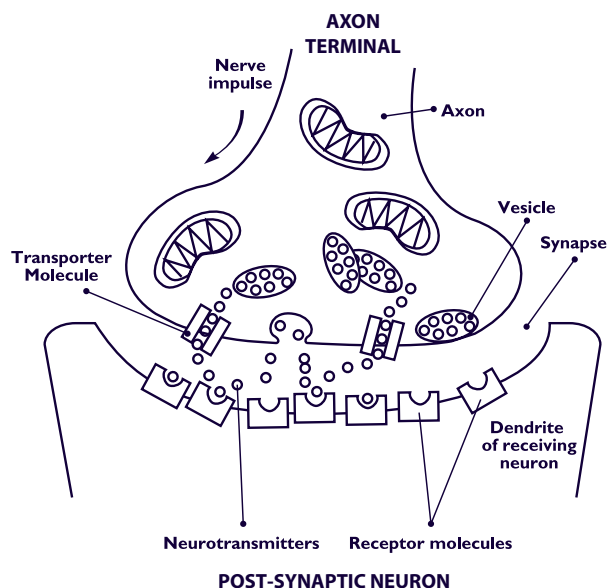
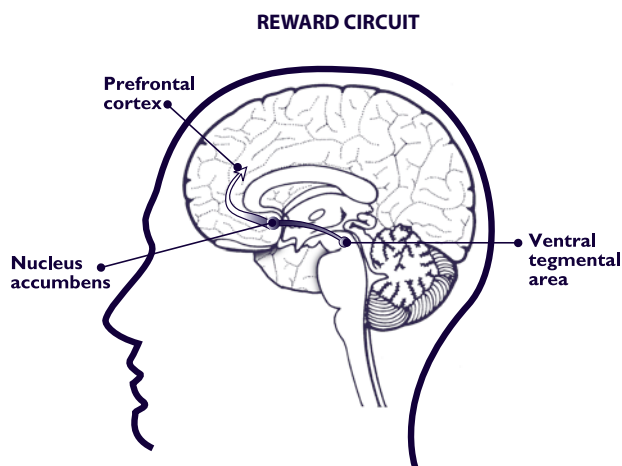


FIGURE 5

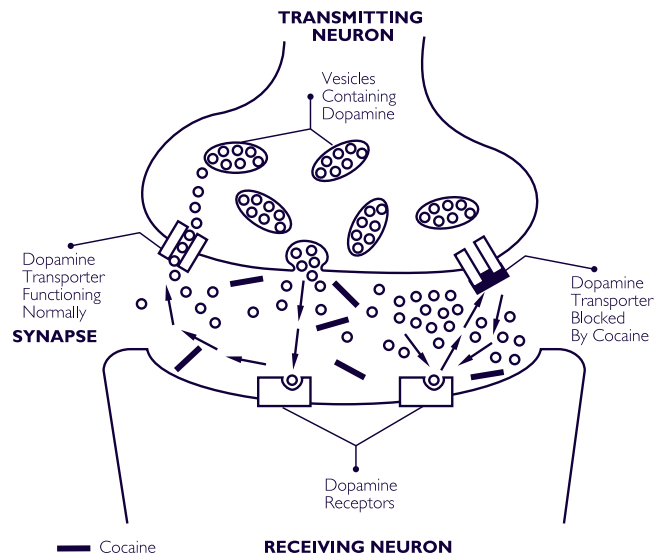
## EFFECTS OF DRUGS OF ABUSE ON THE BRAIN

Pleasure, which scientists call reward, is a very powerful biological force for our survival. If you do something pleasurable, the brain is wired in such a way that you tend to do it again. Life-sustaining activities, such as eating, activate a circuit of specialized nerve cells devoted to producing and regulating pleasure. One important set of these nerve cells, which uses a chemical neurotransmitter called dopamine, sits at the very top of the brainstem in the ventral tegmental area (VTA) (Figure 6). These dopamine-containing neurons relay messages about pleasure through their nerve fibers to nerve cells in a limbic system structure called the nucleus accumbens. Still other fibers reach to a related part of the frontal region of the cerebral cortex. So, the pleasure circuit, which is known as the mesolimbic dopamine system, spans the survival-oriented brainstem, the emotional limbic system, and the frontal cerebral cortex.

All drugs that are addicting can activate the brain's pleasure circuit. Drug addiction is a biological, pathological process that alters the way



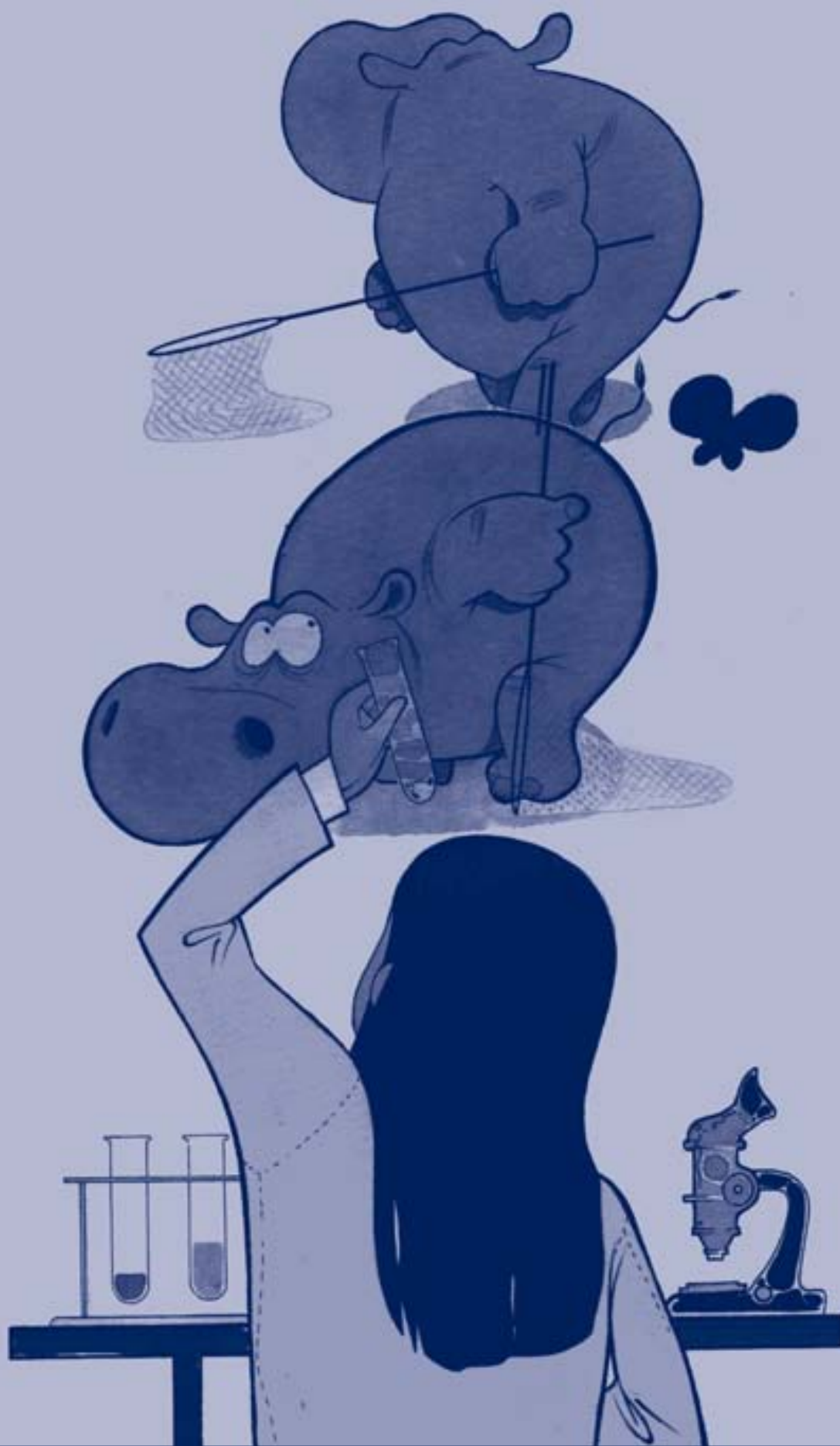
**FIGURE 6** This drawing of a brain cut in half demonstrates the brain areas and pathways involved in the pleasure circuit.



**FIGURE 7** When cocaine enters the brain, it blocks the dopamine transporter from pumping dopamine back into the transmitting neuron, flooding the synapse with dopamine. This intensifies and prolongs the stimulation of receiving neurons in the brain's pleasure circuits, causing a cocaine "high."

in which the pleasure center, as well as other parts of the brain, functions. To understand this process, it is necessary to examine the effects of drugs on neurotransmission. Almost all drugs that change the way the brain works do so by affecting chemical neurotransmission. Some drugs, like heroin and LSD, mimic the effects of a natural neurotransmitter. Others, like PCP, block receptors and thereby prevent neuronal messages from getting through. Still others, like cocaine, interfere with the molecules that are responsible for transporting neurotransmitters back into the neurons that released them (Figure 7). Finally, some drugs, such as methamphetamine, act by causing neurotransmitters to be released in greater amounts than normal.

Prolonged drug use changes the brain in fundamental and long-lasting ways. These long-lasting changes are a major component of the addiction itself. It is as though there is a figurative "switch" in the brain that "flips" at some point during an individual's drug use. The point at which this "flip" occurs varies from individual to individual, but these changes can transform a person from one who uses drugs into a person addicted to drugs.



# Marijuana



## MECHANISM OF ACTION

### BACKGROUND

**Marijuana is the dried leaves and flowers of the cannabis plant. Tetrahydrocannabinol (THC) is the main ingredient in marijuana that causes people who use it to experience a calm euphoria. Marijuana changes brain messages that affect sensory perception and coordination. This can cause users to see, hear, and feel stimuli differently and to exhibit slower reflexes.**

THC, the main active ingredient in marijuana, binds to and activates specific receptors, known as cannabinoid receptors. There are many of these receptors in parts of the brain that control memory, thought, concentration, time and depth perception, and coordinated movement.

By activating these receptors, THC interferes with the normal functioning of the cerebellum, the part of the brain most responsible for balance, posture, and coordination of movement. The cerebellum coordinates the muscle movements ordered by the motor cortex. Nerve impulses alert the cerebellum that the motor cortex has directed a part of the body to perform a certain action. Almost instantly, impulses from that part of the body inform the cerebellum as to how the action is being carried out. The cerebellum compares the actual movement with the intended movement and then signals the motor cortex to make any necessary corrections. In this way, the cerebellum ensures that the body moves smoothly and efficiently.

The hippocampus, which is involved with memory formation, also contains many cannabinoid receptors. Studies have suggested that marijuana activates cannabinoid receptors in the hippocampus and affects memory by decreasing the activity of neurons in this area. The effect of marijuana on long-term memory is less certain, but while someone is under the influence of marijuana, short-term memory can be compromised. Further, research studies have shown chronic administration of THC can permanently damage the hippocampus of rats, suggesting that marijuana use can lead to permanent memory impairment.



# Marijuana

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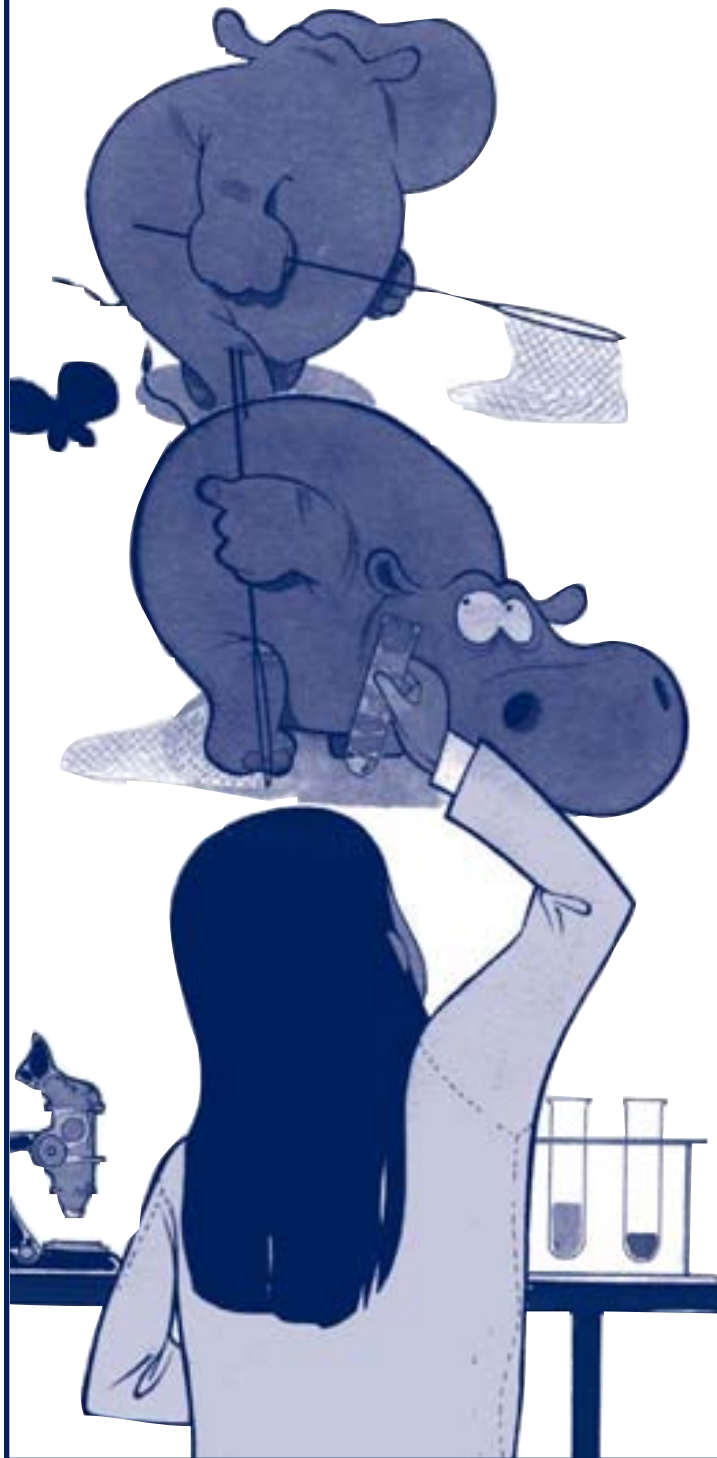
Marijuana also affects receptors in brain areas and structures responsible for sensory perception. Marijuana interferes with the receiving of sensory messages (for example, touch, sight, hearing, taste, and smell) in the cerebral cortex. Various parts of the body send nerve signals to the thalamus, which then routes these messages to the appropriate areas of the cerebral cortex. An area of the sensory cortex, called the somatosensory cortex, receives messages that it interprets as body sensations such as touch and temperature. The somatosensory cortex lies in the parietal lobe of each hemisphere along the central fissure, which separates the frontal and parietal lobes. Each part of the somatosensory cortex receives and interprets impulses from a specific part of the body. Other specialized areas of the cerebrum receive the sensory impulses related to seeing, hearing, taste, and smell. Impulses from the eyes travel along the optic nerve and then are relayed to the visual cortex in the occipital lobes. Portions of the temporal lobes receive auditory messages from the ears. The area for taste lies buried in the lateral fissure, which separates the frontal and temporal lobes. The center for smell is on the underside of the frontal lobes. Marijuana activates cannabinoid receptors in these various areas of the cerebrum and results in the brain misinterpreting the nerve impulses from the different sense organs.

For many years, it was known that THC acted on cannabinoid receptors in the brain. It was

hypothesized that since the normal brain produces these receptors, there must also be a substance produced by the brain itself that acts on these receptors. Despite years of effort, however, the brain's THC-like substance eluded scientists, and whether or not such a substance existed remained a mystery. Finally, in 1992, scientists discovered a substance produced by the brain that activates the THC receptors and has many of the same physiological effects as THC. The scientists named the substance anandamide, from a Sanskrit word meaning bliss. The discovery of anandamide opened whole new avenues of research. For instance, since the brain produces both anandamide and the cannabinoid receptors to which it binds, it was thought that anandamide must play a role in the normal functioning of the brain. Not only are scientists studying anandamide, but more recently additional cannabinoid molecules and receptors have been discovered. One of these, 2-arachidonoglycerol, is a substance that is similar to anandamide, and has a role in controlling pain. Scientists are now actively investigating the function of anandamide and 2-arachidonoglycerol in the brain. The research will not only help in gaining a greater understanding of how marijuana acts in the brain and why it is abused, but it will also provide new clues about how the healthy brain works.



# Marijuana



The discovery of anandamide may also lead to a greater understanding of certain health problems and ultimately to more effective treatments. When made synthetically and given orally, THC can be used to treat nausea associated with chemotherapy and stimulate appetite in AIDS wasting syndrome. Now that the brain's own THC-like substance has been identified, researchers may soon be able to uncover the mechanisms underlying the therapeutic effects of THC. This could then lead to the development of more effective and safer treatments for a variety of conditions.

Recent research in animals has also suggested that long-term use of marijuana (THC) produces some changes in the limbic system that are similar to those that occur after long-term use of other major drugs of abuse such as cocaine, heroin, and alcohol. These changes are most evident during withdrawal from THC. During withdrawal, there are increases in both the levels of a brain chemical involved in stress and certain emotions and the activity of neurons in the amygdala. These same kinds of changes also occur during withdrawal from other drugs of abuse, suggesting that there may be a common factor in the development of drug addiction.

The following activities, when used along with the magazine on marijuana, will help explain to students how these substances change the brain and the body.

# Marijuana



## OBJECTIVES

- ★ **The student will understand the effects of marijuana on brain structures which control the five senses, emotions, memory, and judgment.**
- ★ **The student will use knowledge of brain-behavior relationships to determine the possible effects of marijuana on the ability to perform certain tasks and occupations.**

## MARIJUANA ACTIVITY ONE

Review the way in which marijuana use affects brain regions and structures that control the five senses, heart rate, emotions, memory, and judgment. Students then randomly select (for example, draw from a hat) an occupation and are asked to act-out, in front of the class, how marijuana use might specifically affect the performance of a person in that occupation. Examples of occupations can include: an airline pilot, a professional basketball player, a doctor, a defense attorney, a truck driver, a construction worker, a waiter/waitress, a politician, etc. Students will identify the brain regions and structures affected by marijuana use, and describe the link between these structures and behavior.

## OBJECTIVE

- ★ **The student will understand how marijuana interferes with information transfer and short-term memory.**

## MARIJUANA ACTIVITY TWO

Read a list of 20 words aloud to the class and then ask students to write down as many as they can remember. Then have several students stand, in pairs, at various points in the room and carry on loud conversations while you read a list of 20 new words to the remainder of the class. Ask students to again write down as many words as they can remember. Compare performance between the two trials. Mention to the students that, like the disruptive pairs of students, marijuana interferes with normal information transfer and memory. Students will identify the areas of the brain and structures responsible for these functions and will be reminded that marijuana alters neurotransmission in these areas. Students can also search the Internet and other sources to research the effects of marijuana on information transfer and memory and then prepare a brief report summarizing their findings.

## OBJECTIVE

- ★ **The student will learn more about the important role of the cerebellum.**

## MARIJUANA ACTIVITY THREE

Explain that the cerebellum is involved in balance, coordination, and a variety of other regulatory functions. Marijuana affects the cerebellum, resulting in impairments in motor behavior. Students will search the Internet and other sources for more information about the role and function of the cerebellum and will make a list of ways in which damage to the cerebellum would affect their day-to-day behavior.

# Opiates



## MECHANISM OF ACTION

### BACKGROUND

**Opiates are powerful drugs derived from the poppy plant that have been used for centuries to relieve pain. They include opium, heroin, morphine, and codeine. Even centuries after their discovery, opiates are still the most effective pain relievers available to physicians for treating pain. Although heroin has no medicinal use, other opiates, such as morphine and codeine, are used in the treatment of pain related to illnesses (for example, cancer) and medical and dental procedures. When used as directed by a physician, opiates are safe and generally do not produce addiction. But opiates also possess very strong reinforcing properties and can quickly trigger addiction when used improperly.**

Opiates elicit their powerful effects by activating opiate receptors that are widely distributed throughout the brain and body. Once an opiate reaches the brain, it quickly activates the opiate receptors that are found in many brain regions and produces an effect that correlates with the area of the brain involved. Two important effects produced by opiates, such as morphine, are pleasure (or reward) and pain relief. The brain itself also produces substances known as endorphins that activate the opiate receptors. Research indicates that endorphins are involved in many things, including respiration, nausea, vomiting, pain modulation, and hormonal regulation.

When opiates are prescribed by a physician for the treatment of pain and are taken in the prescribed dosage, they are safe and there is little chance of addiction. However, when opiates are abused and/or taken in excessive doses, addiction can result. Findings from animal research indicate that, like cocaine and other abused drugs, opiates can also activate the brain's reward system. When a person injects, sniffs, or orally ingests heroin (or morphine), the drug travels quickly to the brain through the bloodstream. Once in the brain, the heroin is rapidly converted to morphine, which then activates opiate receptors located throughout the brain, including within the reward system. (Note: Because of its chemical structure, heroin penetrates the brain more quickly than other opiates, which is probably why many addicts prefer heroin.) Within the reward system, the morphine activates opiate receptors in the VTA, nucleus accumbens, and cerebral cortex (refer to the Introduction for information on the reward system). Research suggests that stimulation of opiate receptors by morphine results in feelings of reward and activates the pleasure circuit by causing greater amounts of dopamine to be released within the nucleus accumbens. This causes an intense euphoria, or rush, that lasts only briefly and is followed by a few hours of a relaxed, contented state. This excessive release of dopamine and stimulation of the reward system can lead to addiction.



# Opiates

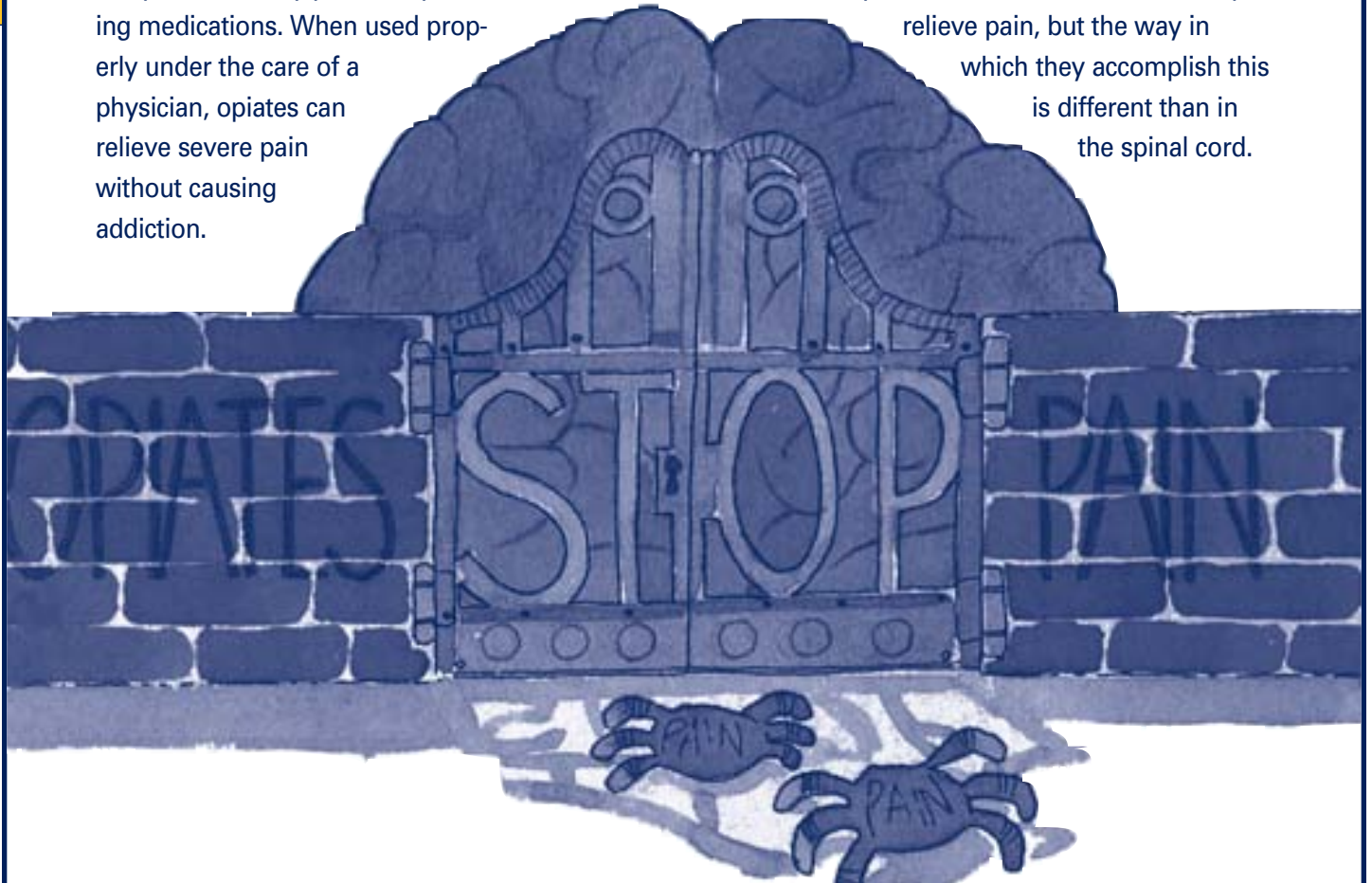
Opiates also act directly on the respiratory center in the brainstem, where they cause a slowdown in activity. This results in a decrease in breathing rate. Excessive amounts of an opiate, like heroin, can cause the respiratory centers to shut down breathing altogether. When someone overdoses on heroin, it is the action of heroin in the brainstem respiratory centers that can cause the person to stop breathing and die.

As mentioned earlier, the brain itself produces endorphins that have an important role in the relief or modulation of pain. Sometimes, though, particularly when pain is severe, the brain does not produce enough endorphins to provide pain relief. Fortunately, opiates, such as morphine are very powerful pain relieving medications. When used properly under the care of a physician, opiates can relieve severe pain without causing addiction.

Feelings of pain are produced when specialized nerves are activated by trauma to some part of the body, either through injury or illness. These specialized nerves, which are located throughout the body, carry the pain message to the spinal cord. After reaching the spinal cord, the message is relayed to other neurons, some of which carry it to the brain. Opiates help to relieve pain by acting in both the spinal cord and brain. At the level of the spinal cord, opiates interfere with the transmission of the pain messages between neurons and therefore prevent them from reaching the brain. This blockade of pain messages protects a person from experiencing too much pain. This is known as analgesia.

Opiates also act in the brain to help relieve pain, but the way in which they accomplish this is different than in the spinal cord.

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# Opiates

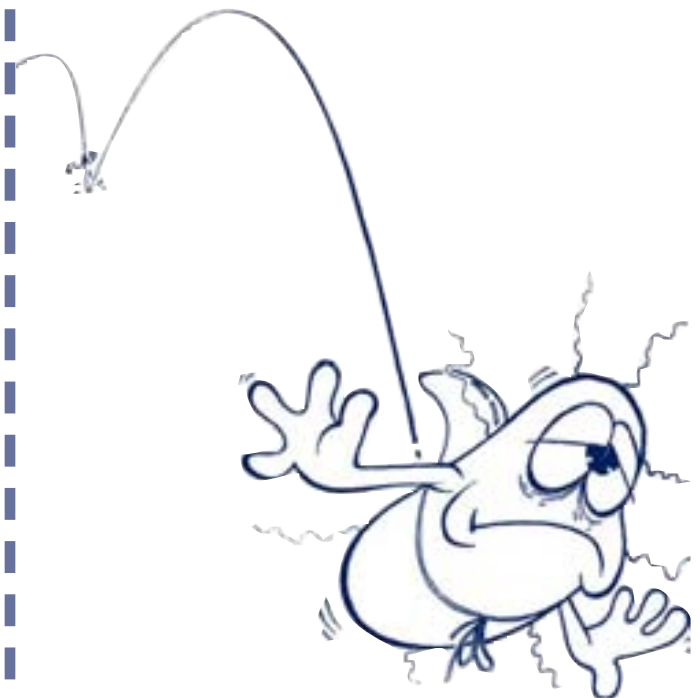
There are several areas in the brain that are involved in interpreting pain messages and in subjective responses to pain. These brain regions are what allow a person to know he or she is experiencing pain and that it is unpleasant. Opiates also act in these brain regions, but they don't block the pain messages themselves. Rather, they change the subjective experience of the pain. This is why a person receiving morphine for pain may say that they still feel the pain but that it doesn't bother them anymore.

Although endorphins are not always adequate to relieve pain, they are very important for survival. If an animal or person is injured and needs to escape a harmful situation, it would be difficult to do so while experiencing severe pain. However, endorphins that are released immediately following an injury can provide enough pain relief to allow escape from a harmful situation. Later, when it is safe, the endorphin levels decrease and intense pain may be felt. This also is important for survival. If the endorphins continued to blunt the pain, it would be easy to ignore an injury and then not seek medical care.

There are several types of opiate receptors, including the delta, mu, and kappa receptors. Each of these three receptors is involved in controlling different brain functions. For example, opiates and endorphins are able to block pain signals by binding to the mu receptor site.

The powerful technology of cloning has enabled scientists to copy the genes that make each of these receptors. This in turn is allowing researchers to conduct laboratory studies to better understand how opiates act in the brain and, more specifically, how opiates interact with each opiate receptor to produce their effects. This information may eventually lead to more effective treatments for pain and opiate addiction.

The following activities, when used along with the magazine on opiates, will help explain to students how these substances change the brain and the body.



# Opiates



## OBJECTIVE

- ★ **The student will learn the way in which opiates alter the function of nerve cells.**

## OPIATES ACTIVITY ONE

Remind students that long-term abuse of opiates, such as heroin, changes the way nerve cells in the brain work. These cells become so used to having the heroin present that they need it to work normally. This, in turn, leads to addiction. If opiates are taken away from dependent nerve cells, these cells become overactive. Eventually, they will work normally again, but in the meantime, they create a range of symptoms known as withdrawal. Have students create visual representations of normal nerve cells, dependent nerve cells, overactive nerve cells, and an opiate. Then have the students use these representations to develop, in comic art format, the process by which opiates change the normal functioning of neurons.

## OBJECTIVE

- ★ **The student will learn how opiates produce an analgesic effect.**

## OPIATES ACTIVITY TWO

Note that opiates are powerful painkillers and are used medically for treatment of pain. When used properly for medical purposes, opiates do not produce an intense feeling of pleasure, and patients have little chance of becoming addicted. Have students search the Internet and other sources for information about pain, pain control, and the way opiates produce their analgesic effect and then prepare a brief summary report.

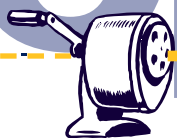
## OBJECTIVE

- ★ **The student will become more familiar with neuroscience concepts and terminology associated with the effects of opiates on the brain.**

## OPIATES ACTIVITY THREE

Students will solve a crossword puzzle which requires knowledge of the ways in which opiates affect brain anatomy and physiology. The puzzle and solution is included in the guide.

# Opiates



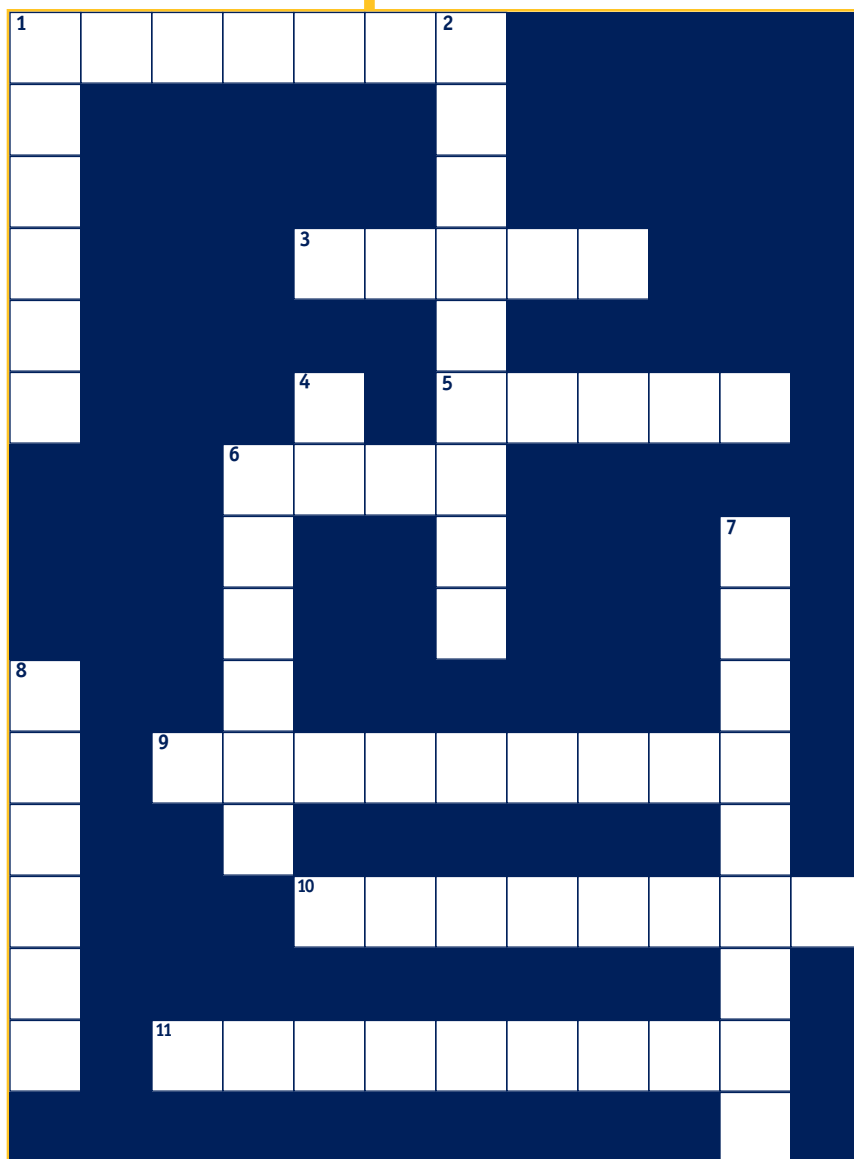
## CROSSWORD PUZZLE

### ACROSS

- 1 Space between neurons
- 3 Copy genetic material to produce an identical cell
- 5 Opiates come from this plant
- 6 Feeling of euphoria
- 9 Controls breathing and heart rate
- 10 Pleasure neurotransmitter
- 11 Pain relief

### DOWN

- 1 Opiates act on the \_\_\_\_\_ cord and brain
- 2 Pain reliever produced by brain
- 4 An opiate receptor
- 6 Another name for pleasure
- 7 Ventral \_\_\_\_\_ area
- 8 Powerful opiate



## SOLUTION

[illegible]

# Inhalants



## MECHANISM OF ACTION

### BACKGROUND

Most inhalants are common household products that give off mind-altering chemical fumes when sniffed. These common products include paint thinner, fingernail polish remover, glues, gasoline, cigarette lighter fluid, and nitrous oxide. They also include fluorinated hydrocarbons found in aerosols, such as whipped cream, hair and paint sprays, and computer cleaners. The chemical structure of the various types of inhalants is diverse, making it difficult to generalize about the effects of inhalants. It is known, however, that the vaporous fumes can change brain chemistry and may be permanently damaging to the brain and central nervous system.

Inhalant users are also at risk for Sudden Sniffing Death (SSD), which can occur when the inhaled fumes take the place of oxygen in the lungs and central nervous system. This basically causes the inhalant user to suffocate. Inhalants can also lead to death by disrupting the normal heart rhythm, which can lead to cardiac arrest. Use of inhalants can cause hepatitis, liver failure, and muscle weakness. Certain inhalants can also cause the body to produce fewer of all types of blood cells, which may result in life-threatening aplastic anemia.

Inhalants also alter the functioning of the nervous system. Some of these effects are transient and disappear after use is discontinued. But inhalant use can also lead to serious neurological problems, some of which are irreversible. For example, frequent long-term use of certain inhalants can cause a permanent change or malfunction of nerves in the back and legs, called polyneuropathy. Inhalants can also act directly in the brain to cause a variety of neurological problems. For instance, inhalants can cause abnormalities in brain areas that are involved in movement (for example, the cerebellum) and higher cognitive function (for example, the cerebral cortex).

Inhalants enter the bloodstream quickly and are then distributed throughout the brain and body. They have direct effects on both the central nervous system (brain and spinal cord) and the peripheral nervous system (nerves throughout the body).

Using brain imaging techniques, such as magnetic resonance imaging (MRI), researchers have discovered that there are marked structural changes in the brains of chronic inhalant abusers. These changes include a reduction in size in certain brain areas, including the cerebral cortex, cerebellum, and brainstem. These changes may account for some of the neurological and behavioral symptoms that long-term inhalant abusers exhibit (for example, cognitive and motor difficulties). Some of these changes may be due to the effect inhalants have on myelin, the fatty tissue which insulates and protects axons and helps speed up nerve conduction. When inhalants enter the brain and body, they are particularly attracted to fatty tissues. Because myelin is a fat, it quickly absorbs inhalants, which can then damage or even destroy the myelin. The deterioration of myelin interferes with the rapid flow of messages from one nerve to another.

Inhalants can also have a profound effect on nerves that are located throughout the body. The polyneuropathy caused by some inhalants, as well as other neurological problems, may be due in part to the effect of the inhalants on the myelin sheath that covers axons throughout the body. In some cases, not only is the myelin destroyed, but the axons themselves degenerate.

The following activities, when used along with the magazine on inhalants, will help explain to students how these substances change the brain and the body.

# Inhalants



## OBJECTIVE

- ★ **The student will learn the effects of inhalant use on brain-behavior relationships.**

## INHALANTS ACTIVITY ONE

Introduce this activity by reminding students that inhalants can slow or stop nerve cell activity in some parts of the brain; for example, the frontal lobes (complex problem solving), cerebellum (movement and coordination), and hippocampus (memory). Students will break into small groups and contribute in a round-robin fashion to a story about a fictional student who uses inhalants. The students should be encouraged to include problems (symptoms) in the description that would be associated with inhalant use, as well as other symptoms that would not. These stories can then be shared (either in oral or written form) with the rest of the class, who will be required to identify the inhalant-related behavioral components and then describe the brain areas that are involved in these behaviors. Students will then search the Internet and other sources to obtain information about the way in which activity in the frontal lobes, cerebellum, and hippocampus influences behavior, and prepare a report summarizing their findings.

## OBJECTIVE

- ★ **The student will understand the effect of inhalants on brain structures, physiology, and behavior.**

## INHALANTS ACTIVITY TWO

Review the regions of the brain and structures affected by inhaling solvents, gases, and nitrites. Then divide the class into groups of 4-6, and have each group write a rap music video about the effects of inhalants on brain areas and structures, as well as brain-behavior relationships. When the songs are finished, have each group perform their music video.

## OBJECTIVE

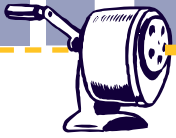
- ★ **The student will become more familiar with the neuroscience concepts and terminology associated with the effects of inhalants on the brain and body.**

## INHALANTS ACTIVITY THREE

The students will complete the Inhalants Word Search, and the teacher will then review the words and have the students discuss how the terms relate to inhalant use. A copy of the Word Search and the Word Search Solution is included in the guide.



# Inhalants



## WORD SEARCH

A	A	L	A	D	G	Y	M	A	N	Y
Z	U	X	I	I	M	P	A	M	A	V
S	D	B	F	N	Z	J	L	R	C	P
H	J	P	W	H	M	G	R	O	E	S
B	N	O	X	A	I	S	O	P	R	B
A	F	L	J	L	K	O	W	A	E	W
T	E	Y	K	A	I	B	Y	V	B	E
D	V	N	K	N	D	V	B	S	E	Q
C	S	E	G	T	N	N	E	U	L	G
B	G	U	K	C	E	L	L	R	L	S
T	X	R	F	L	Y	P	L	M	U	X
I	E	O	R	F	U	M	E	S	M	F
D	T	P	F	W	O	K	R	Y	O	N
J	R	A	X	F	A	C	E	C	P	R
C	O	T	F	Y	I	L	A	Z	U	Y
T	C	H	L	X	I	N	B	T	D	I
E	H	Y	H	N	X	V	S	T	E	C
U	E	O	R	L	N	Q	O	H	A	G

Amygdala

Fumes

Myelin

Axon

Glue

Polyneuropathy

Cell

Inhalant

Sniff

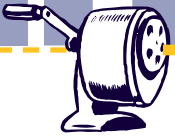
Cerebellum

Kidney

Vapor

Cortex

Liver



## WORD SEARCH

A	A	L	A	D	G	Y	M	A	N	Y
Z	U	X	I	I	M	P	A	M	A	V
S	D	B	F	N	Z	J	L	R	C	P
H	J	P	W	H	M	G	R	O	E	S
B	N	O	X	A	I	S	O	P	R	B
A	F	L	J	L	K	O	W	A	E	W
T	E	Y	K	A	I	B	Y	V	B	E
D	V	N	K	N	D	V	B	S	E	Q
C	S	E	G	T	N	N	E	U	L	G
B	G	U	K	C	E	L	L	R	L	S
T	X	R	F	L	Y	P	L	M	U	X
I	E	O	R	F	U	M	E	S	M	F
D	T	P	F	W	O	K	R	Y	O	N
J	R	A	X	F	A	C	E	C	P	R
C	O	T	F	Y	I	L	A	Z	U	Y
T	C	H	L	X	I	N	B	T	D	I
E	H	Y	H	N	X	V	S	T	E	C
U	E	O	R	L	N	Q	O	H	A	G

Amygdala

Fumes

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Vapor

Cortex

Liver

# Hallucinogens



## BACKGROUND

Hallucinogens are drugs which cause altered states of perception and feeling and which can produce flashbacks. They include natural substances, such as mescaline and psilocybin that come from plants (cactus and mushrooms), and chemically manufactured ones, such as LSD and MDMA (ecstasy). LSD is manufactured from lysergic acid, which is found in ergot, a fungus that grows on rye and other grains. MDMA is a synthetic mind-altering drug with both stimulant and hallucinogenic properties.

Although not a true hallucinogen in the pharmacological sense, PCP causes many of the same effects as hallucinogens and so is often included with this group of drugs. Hallucinogens have powerful mind-altering effects. They can change how the brain perceives time, everyday reality, and the surrounding environment. They affect regions and structures in the brain that are responsible for coordination, thought processes, hearing, and sight. They can cause people who use them to hear voices, see images, and feel sensations that do not exist. Researchers are not certain that brain chemistry permanently changes from hallucinogen use, but some people who use them appear to develop chronic mental disorders. PCP and MDMA can be addictive; whereas LSD, psilocybin, and mescaline are not.

Research has provided many clues about how hallucinogens act in the brain to cause their powerful effects. However, because there are different types of hallucinogens and their effects are so widespread, there is still much that is unknown. The following paragraphs describe some of what is known about this diverse group of drugs.

## MECHANISM OF ACTION

LSD binds to and activates a specific receptor for the neurotransmitter serotonin. Normally, serotonin binds to and activates its receptors and then is taken back up into the neuron that released it. In contrast, LSD binds very tightly to the serotonin receptor, causing a greater than normal activation of the receptor. Because serotonin has a role in many of the brain's functions, activation of its receptors by LSD produces widespread effects, including rapid emotional swings, and altered perceptions, and if taken in a large enough dose, delusions and visual hallucinations.

MDMA, which is similar in structure to methamphetamine and mescaline, causes serotonin to be released from neurons in greater amounts than normal. Once released, this serotonin can excessively activate serotonin receptors. Scientists have also shown that MDMA causes excess dopamine to be released from dopamine-containing neurons. Particularly alarming is research in animals that has demonstrated that MDMA can damage serotonin-containing neurons. MDMA can cause confusion, depression, sleep problems, drug craving, and severe anxiety.

PCP, which is not a true hallucinogen, can affect many neurotransmitter systems. It interferes with the functioning of the neurotransmitter glutamate, which is found in neurons throughout the brain. Like many other drugs, it also causes dopamine to be released from neurons into the synapse. At low to moderate doses, PCP causes altered perception of body image, but rarely produces visual hallucinations. PCP can also cause effects that mimic the primary symptoms of schizophrenia, such as delusions and mental turmoil. People who use PCP for long periods of time have memory loss and speech difficulties.

The following activities, when used along with the magazine on hallucinogens, will help explain to students how these substances change the brain and the body.

# Hallucinogens



## OBJECTIVE

- ★ **The student will learn how hallucinogens cause visual misperception and hallucinations.**

## HALLUCINOGENS ACTIVITY ONE

Have students draw a bull's-eye onto a sheet of unruled white paper. Make a small "X" at the center of another sheet of paper. Now, have the students stare at the bull's-eye for about 20 seconds and then quickly shift their focus to the "X." Students will find that an after-image of the bull's-eye will appear. Explain that after-images are a class of optical illusions, which have some similarity to hallucinations. Have students search the Internet and other sources for information about drug-induced hallucinations and prepare a report summarizing their findings.

## OBJECTIVE

- ★ **The student will learn that hallucinogens cause other sensory misperceptions.**

## HALLUCINOGENS ACTIVITY TWO

Fill one bowl with warm water, another with cold water, and a third with water at room temperature. First, have the students place the fingers of one hand in the warm water. Wait 60 seconds. Then have them place their fingers in the room temperature water and describe the temperature of the water (feels cool). Then have the students place their fingers of the other hand in the cold water. Wait 60 seconds. Then have them place their fingers in the room temperature water and describe the temperature of the water (feels hot). Remind students that hallucinogens can affect the way we perceive reality.

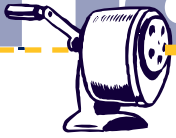
## OBJECTIVE

- ★ **The student will learn vocabulary and facts associated with hallucinogens.**

## HALLUCINOGENS ACTIVITY THREE

Instruct the students to complete the Hallucinogens Word Puzzle. The puzzle and solution to the puzzle are included in the guide.

# Hallucinogens



## WORD PUZZLE

Answer each question below, then correctly arrange the boxed letters to solve the riddle at the bottom of the page.

1 \_\_\_\_\_  \_\_\_\_\_  \_\_\_\_\_  
LSD binds tightly to and activates the receptor for what neurotransmitter?

2 \_\_\_\_\_  \_\_\_\_\_  
What drug comes from a cactus plant?

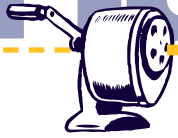
3 \_\_\_\_\_  \_\_\_\_\_  
What is another name for MDMA?

4  \_\_\_\_\_  \_\_\_\_\_  
Neurotransmitters attach to what molecules in the cell membrane?

5 \_\_\_\_\_  \_\_\_\_\_  
What is another name for LSD?

6  \_\_\_\_\_  
Changes in what brain structure affect breathing and heart rate?

**What might result if you use either  
hallucinogens, or a lousy travel agent?**



## WORD PUZZLE

SOLUTION

Answer each question below, then correctly arrange the boxed letters to solve the riddle at the bottom of the page.

1

S E R O T O N I N

LSD binds tightly to and activates the receptor for what neurotransmitter?

2

M E S C A L I N E

What drug comes from a cactus plant?

3

E C S T A C Y

What is another name for MDMA?

4

R E C E P T O R S

Neurotransmitters attach to what molecules in the cell membrane?

5

A C I D

What is another name for LSD?

6

B R A I N S T E M

Changes in what brain structure affect breathing and heart rate?

A

B

A

D

T

R

I

P

**What might result if you use either hallucinogens, or a lousy travel agent?**



# Steroids



## MECHANISM OF ACTION

## BACKGROUND

**Anabolic steroids are chemicals that are similar to the male sex hormone testosterone and are used by an increasing number of young people to enhance their muscle size. While anabolic steroids are quite successful at building muscle, they can damage many body organs, including the liver, kidneys, and heart. They may also trigger dependency in users, particularly when taken in the large doses that have been known to be used by many bodybuilders and athletes.**

Anabolic steroids are taken either orally in pill form or by injection. After steroids enter the bloodstream, they are distributed to organs (including muscle) throughout the body. After reaching these organs, the steroids surround individual cells in the organ and then pass through the cell membranes to enter the cytoplasm of the cells. Once in the cytoplasm, the steroids bind to specific receptors and then enter the nucleus of the cells. The steroid-receptor complex is then able to alter the functioning of the genetic material and stimulate the production of new proteins. It is these proteins that carry out the effects of the steroids. The types of proteins and the effects vary depending on the specific organ involved. Steroids are able to alter the functioning of many organs, including the liver, kidneys, heart, and brain. They can also have a profound effect on reproductive organs and hormones.

Many of the effects of steroids are brought about through their actions in the brain. Once steroids enter the brain, they are distributed to many regions, including the hypothalamus and limbic system. When a person takes steroids, the functioning of neurons in both of these areas is altered, resulting in a change in the types of messages that are transmitted by the neurons. Since the hypothalamus has a major role in maintaining normal hormone levels, disrupting its normal functioning also disrupts the body's hormones. This can result in many problems, including a reduction in normal testosterone production in males and loss of the monthly period in females.

Similarly, steroids can also disrupt the functioning of neurons in the limbic system. The limbic system is involved in many things, including learning, memory, and regulation of moods. Studies in animals have shown that steroids can impair learning and memory. They can also promote overly-aggressive behavior and mood swings. People who take anabolic steroids can exhibit violent behavior, impairment of judgment, and even psychotic symptoms.

Other effects of taking anabolic steroids include changes in male and female sexual characteristics, stunted growth, and an increase in the amount of harmful cholesterol in the body. Anabolic steroids can also influence the growth of facial and chest hair and cause a deepening of the voice.

The following activities, when used along with the magazine on anabolic steroids, will help explain to students how these substances change the brain and the body.

# Steroids



## OBJECTIVE

- ★ **The student will understand that steroids have a direct effect on the limbic system, which has a large role in the expression of emotions.**

## STERIODS ACTIVITY ONE

Ask students to imagine a time when they experienced, very suddenly, either intense rage or aggressiveness. Those who would like to can share some of these experiences with the class. Reinforce that the limbic system was likely involved in these reactions and that steroid use directly increases the likelihood of such episodes. Mention that neuroscientists have long known about the important role the limbic system plays in emotions and have conducted animal research in which stimulating certain limbic system structures produces a rage reaction in a normally docile animal, while stimulating other structures makes a normally vicious animal calm and relaxed. Have students conduct research using the Internet and other sources to learn more about the role of the limbic system.

## OBJECTIVE

- ★ **The student will learn more about the functions of key neurotransmitters including serotonin, glutamate, dopamine, and acetylcholine.**

## STERIODS ACTIVITY TWO

Indicate that steroids affect the function of several neurotransmitters, adding that each neurotransmitter communicates different types of messages. For example, glutamate communicates excitement, acetylcholine tells the heart to beat slower and commands memory circuits to store or remember thoughts, serotonin controls emotions and mood, and dopamine affects feelings of pleasure. Students will select a neurotransmitter and search the Internet and other sources for additional information. They will prepare a brief report summarizing their findings and create a comic art rendition of their neurotransmitter.

## OBJECTIVE

- ★ **The student will learn about the performance enhancing effects of steroids, and the medical risk factors.**

## STERIODS ACTIVITY THREE

Remind students that despite their dangerous side effects, anabolic steroids are used by some high school, college, and professional athletes to give them the “edge” they feel they need to outperform the competition. Discuss with the students the short- and long-term dangers associated with the use of steroids for enhancing performance. A useful example for this discussion might be Lyle Alzado, a former professional football star who died from cancer attributed to steroid use.

# Stimulants



## MECHANISM OF ACTION

### BACKGROUND

**Stimulant drugs such as cocaine, “crack,” amphetamines, and caffeine are substances that speed up activity in the brain and spinal cord. This, in turn, can cause the heart to beat faster and blood pressure and metabolism to increase. Stimulants often influence a person to be more talkative and anxious and to experience feelings of exhilaration.**

**Use of cocaine and other stimulants can cause someone’s heart to beat abnormally fast and at an unsteady rate. Use of these drugs also narrows blood vessels, reducing the flow of blood and oxygen to the heart, which results in “starving” the heart muscle. Even professional athletes whose bodies are well-conditioned have succumbed to cocaine’s ability to cause heart failure. Researchers currently have no way to detect who may be more susceptible to these effects.**

Cocaine acts on the pleasure circuit to prevent reabsorption of the neurotransmitter dopamine after its release from nerve cells. Normally, neurons that are part of the pleasure circuit release dopamine, which then crosses the synapse to stimulate another neuron in the pleasure circuit. Once this has been accomplished, the dopamine is picked up by a transporter molecule and carried back into the original neuron. However, because cocaine binds to the dopamine transporter molecule, it prevents the reabsorption of dopamine. This causes a buildup of dopamine in the synapse, which results in strong feelings of pleasure and even euphoria. The excess dopamine that accumulates in the synapse causes the neurons that have dopamine receptors to decrease the number of receptors they make. This is called down regulation. When cocaine is no longer taken and dopamine levels return to their normal (i.e., lower) concentration, the smaller number of dopamine receptors that are available for the neurotransmitter to bind to is insufficient to fully activate nerve cells. During “craving,” the addict experiences a very strong need for the drug to get the level of dopamine back up. Cocaine also binds to the transporters for other neurotransmitters, including serotonin and norepinephrine, and blocks their re-uptake. Scientists are still unsure about the effects of cocaine’s interaction with these other neurotransmitters.

Cocaine has also been found to specifically affect the pre-frontal cortex and amygdala, which are involved in aspects of memory and learning. The amygdala has been linked to emotional aspects of memory. Researchers believe that a neural network involving these brain regions reacts to environmental cues and activates memories, and this triggers biochemical changes that result in cocaine craving.

# Stimulants

Amphetamines, such as methamphetamine, also act on the pleasure circuit by altering the levels of certain neurotransmitters present in the synapse, but the mechanism is different from that of cocaine. Methamphetamine is chemically similar to dopamine. This similarity allows methamphetamine to fool the dopamine transporter into carrying methamphetamine into the nerve terminal. Methamphetamine can also directly cross nerve cell membranes. Once inside nerve terminals, methamphetamine enters dopamine vesicles and causes the release of these neurotransmitters. The excess dopamine is then carried by transporter molecules out of the neuron and into the synapse. Once in the synapse, the high concentration of dopamine causes feelings of pleasure and euphoria.

Methamphetamine also differs from cocaine in that it can damage neurons that contain dopamine and even kill neurons that contain other neurotransmitters. This cell damage can occur in the frontal cortex, amygdala and the striatum, a brain region that is involved in movement. This may account for the dramatic

decrease in dopamine levels seen with brain imaging techniques in both humans and animals. These decreases in dopamine are seen even after short-term exposure to methamphetamine and they persist for many years, even after methamphetamine use has been terminated.

For more information on how methamphetamine acts in the brain, see the last chapter which is devoted entirely to methamphetamine.

The following activities, when used along with the magazine on stimulants, will help explain to students how these substances change the brain and the body.



# Stimulants



## OBJECTIVE

- ★ The student will learn that cocaine affects neurotransmission in the mesolimbic dopamine system, sometimes referred to as the pleasure center.

## COCAINE ACTIVITY ONE

Remind students that cocaine activates the brain's pleasure center, which involves the brainstem, limbic system, and frontal cortex. Students will then produce colorful diagrams of the system, labeling important parts, and provide a brief written description of the different structures.

## OBJECTIVES

- ★ The student will learn the way in which dopamine is related to the sensation of pleasure.
- ★ The student will learn how stimulants interfere with dopamine re-uptake.

## COCAINE ACTIVITY TWO

Describe how cocaine ultimately reduces pleasure by interfering with dopamine re-uptake. Students will be assigned to groups and will first script and then act out this process. They will then perform their skits with students assuming roles such as neurons, cocaine, transporters, receptors, dopamine, pleasure, and addiction.

## OBJECTIVE

- ★ The student will learn and share interesting and unusual information about the effects of cocaine, amphetamines, and caffeine on the brain and behavior.

## COCAINE ACTIVITY THREE

Divide the students into three groups (cocaine, amphetamines, and caffeine), and assign each group the task of researching their assigned drug in order to develop a "Did You Know" poster for each type of drug. Encourage each group to discover some "surprising" information to include on their poster, and ask that each poster contain a minimum of 10 new and/or unusual facts. Students will use the local public library, the Internet, other multimedia materials, and any other sources to obtain this information. They will then work together to develop the graphics and text. Display the finished posters.







# Nicotine



## MECHANISM OF ACTION

### BACKGROUND

**Tobacco, which comes primarily from the plant *nicotiana tabacum*, has been used for centuries. It can be smoked, chewed, or sniffed. The first description of addiction to tobacco is contained in a report from the New World in which Spanish soldiers said that they could not stop smoking.**

**When nicotine was isolated from tobacco leaves in 1828, scientists began studying its effects in the brain and body.**

**This research eventually showed that, although tobacco contains thousands of chemicals, the main ingredient that acts in the brain and produces addiction is nicotine. More recent research has shown that the addiction produced by nicotine is extremely powerful and is at least as strong as addictions to other drugs such as heroin and cocaine.**

**Some of the effects of nicotine include changes in respiration and blood pressure, constriction of arteries, and increased alertness. Many of these effects are produced through its action on both the central and peripheral nervous systems.**

Nicotine readily enters the body. When tobacco is smoked, nicotine enters the bloodstream through the lungs. When it is sniffed or chewed, nicotine passes through the mucous membranes of the mouth or nose to enter the bloodstream. Nicotine can also enter the bloodstream by passing through the skin. Regardless of how nicotine reaches the bloodstream, once there, it is distributed throughout the body and brain where it activates specific types of receptors known as cholinergic receptors.

Cholinergic receptors are present in many brain structures, as well as in muscles, adrenal glands, the heart, and other body organs. These receptors are normally activated by the neurotransmitter acetylcholine, which is produced in the brain, and by neurons in the peripheral nervous system. Acetylcholine and its receptors are involved in many activities, including respiration, maintenance of heart rate, memory, alertness, and muscle movement.

Because the chemical structure of nicotine is similar to that of acetylcholine, it is also able to activate cholinergic receptors. But unlike acetylcholine, when nicotine enters the brain and activates cholinergic receptors, it can disrupt the normal functioning of the brain.

Regular nicotine use causes changes in both the number of cholinergic receptors and the sensitivity of these receptors to nicotine and acetylcholine. Some of these changes may be responsible for the development of tolerance to nicotine. Tolerance occurs when more drug is needed to achieve the same or similar effects. Once tolerance has developed, a nicotine user must regularly supply the brain with nicotine in order to maintain normal brain functioning. If nicotine levels drop, the nicotine user will begin to feel uncomfortable withdrawal symptoms.

# Nicotine

Recently, research has shown that nicotine also stimulates the release of the neurotransmitter dopamine in the brain's pleasure circuit. Using microdialysis, a technique that allows minute quantities of neurotransmitters to be measured in precise brain areas, researchers have discovered that nicotine causes an increase in the release of dopamine in the nucleus accumbens. This release of dopamine is similar to that seen for other drugs of abuse, such as heroin and cocaine, and is thought to underlie the pleasurable sensations experienced by many smokers.

Other research is providing even more clues as to how nicotine may exert its effects in the brain. Cholinergic receptors are relatively large structures that consist of several components known as subunits. One of these subunits, the  $\beta$  (beta) subunit, has recently been implicated in nicotine addiction. Using highly sophisticated bioengineering technologies, scientists were able to produce a new strain of mice in which the gene that produces the  $\beta$  subunit was missing. Without the gene for the  $\beta$  subunit, these mice, which are known as "knock-

out" mice because a particular gene has been knocked out, were unable to produce any  $\beta$  subunits. What researchers found when they examined these knockout mice was that in contrast to mice who had an intact receptor, mice without the  $\beta$  subunit would not self-administer nicotine. These studies demonstrate that the  $\beta$  subunit plays a critical role in the addictive properties of nicotine. The results also provide scientists with valuable new information about how nicotine acts in the brain, information that may eventually lead to better treatments for nicotine addiction.

However, nicotine may not be the only psychoactive ingredient in tobacco. Using advanced brain imaging technology, it is possible to actually see what tobacco smoking is doing to the brain of an awake and behaving human being. Using one type of brain imaging, positron emission tomography (PET), scientists discovered that cigarette smoking causes a dramatic decrease in the levels of an important enzyme that breaks down dopamine and other neurotransmitters.



# Nicotine

The decrease in this enzyme, known as monoamine-oxidase-A (MAO-A), results in an increase in dopamine levels. Importantly, this particular effect is not caused by nicotine but by some additional, unknown compound in cigarette smoke. Nicotine itself does not alter MAO-A levels; it affects dopamine through other mechanisms. Thus, there may be multiple routes by which smoking alters the neurotransmitter dopamine to ultimately produce feelings of pleasure and reward.

That nicotine is a highly addictive drug can clearly be seen when one considers the vast number of people who continue to use tobacco products despite their well known harmful and even lethal effects. In fact, at least 90% of smokers would like to quit, but each year fewer than 10% who try are actually successful. But, while nicotine may produce addiction to tobacco products, it is the thousands of other chemicals in tobacco that are responsible for its many adverse health effects.

Smoking either cigarettes or cigars can cause respiratory problems, lung cancer, emphysema, heart problems, and peripheral vascular disease. In fact, smoking is the largest preventable cause of premature death and disability. Cigarette smoking kills at least 400,000 people in the United States each year and makes countless others ill, including those who are exposed to secondhand smoke. The use of smokeless tobacco is also associated with serious health problems.

Chewing tobacco can cause cancers of the oral cavity, pharynx, larynx, and esophagus. It also causes damage to gums that may lead to the loss of teeth. Although popular among sports figures, smokeless tobacco can also reduce physical performance.

The following activities, when used along with the magazine on nicotine, will help explain to students how these substances change the brain and the body.



# Nicotine



## OBJECTIVE

- ★ **The student will become more familiar with the neuroscience concepts and terminology associated with the effects of nicotine and tobacco products on the brain and body.**

## OBJECTIVE

- ★ **The student will understand that nicotine is a highly addictive drug and that once someone has become addicted, it is very difficult to stop smoking, even in the face of serious health consequences.**

## OBJECTIVE

- ★ **The student will learn that cigarette smoke contains molecules that are deposited along the entire respiratory tract, including the lungs. These molecules not only turn the lungs and other parts of the respiratory system black, but they also cause cancers and other respiratory illnesses.**

## NICOTINE ACTIVITY ONE

The students will complete the Nicotine Word Find, and the teacher will then review the words and have the students discuss how the terms relate to tobacco use. A copy of the Word Search and Word Search Solution is included in the guide.

## NICOTINE ACTIVITY TWO

The students will call local hospitals to obtain the names of physicians who provide treatment to people trying to stop their use of tobacco products. The students will then compose a letter to one or more of these physicians inviting them to come and speak to the class on the difficulties associated with quitting smoking or the use of other tobacco products. Prior to the visit by the physician, the students will prepare a list of questions that they would like to ask. These questions might include the following: 1) How many people succeed the first or even second time they try to stop smoking? 2) How many people try repeatedly to quit smoking without success? 3) Do people still smoke even when they have a life-threatening illness, such as heart disease or lung cancer?

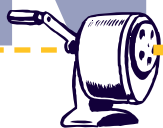
## NICOTINE ACTIVITY THREE

The students will conduct the following experiment:

Materials needed: cigarette, transparent plastic syringe, cotton balls, matches or lighter

Fill the syringe with the cotton balls. Insert the end of the syringe onto the filter of the cigarette. Light the cigarette and pull back the plunger to draw smoke into the barrel of the syringe. Have the students watch the cotton balls turn black as the smoke particles are deposited. Discuss with the students what they have observed. Students might consider what the effects of smoking several cigarettes a day for many years would have on the lungs if only one cigarette can turn a cotton ball black.

# Nicotine



## WORD SEARCH

A	Z	W	S	A	M	E	S	Y	H	P	M	E
R	O	T	P	E	C	E	R	Q	Y	I	N	P
R	E	S	L	O	L	J	G	T	R	I	E	N
B	N	I	A	R	B	U	O	D	L	P	U	M
L	R	Z	W	A	R	T	M	O	O	T	R	K
O	X	Q	A	D	E	I	H	P	R	Z	O	R
O	Q	A	R	W	O	C	C	A	B	O	T	N
D	S	E	D	E	L	D	G	M	R	F	R	O
S	Y	G	H	Y	U	I	J	I	K	I	A	I
T	X	P	T	C	C	L	V	N	J	B	N	T
R	N	E	I	M	A	R	T	E	Y	I	S	C
E	C	Q	W	O	Z	C	D	O	P	M	M	I
A	D	D	R	Y	C	T	A	R	E	N	I	D
M	O	T	K	Z	Q	P	O	N	A	T	T	D
N	E	T	T	E	R	A	G	I	C	W	T	A
G	E	U	N	I	C	O	T	I	N	E	E	L
A	L	S	G	N	I	K	O	M	S	I	R	R

EMPHYSEMA

NEUROTRANSMITTER

CIGAR

DOPAMINE

ADDICTION

REWARD

SMOKING

WITHDRAWAL

CIGARETTE

CANCER

DRUG

ACETYLCHOLINE

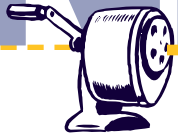
BRAIN

BLOODSTREAM

RECEPTOR

NICOTINE

TOBACCO



# Nicotine

## WORD SEARCH

SOLUTION

A	Z	W	S	A	M	E	S	Y	H	P	M	E
R	O	T	P	E	C	E	R	Q	Y	I	N	P
R	E	S	L	O	L	J	G	T	R	I	E	N
B	N	I	A	R	B	U	O	D	L	P	U	M
L	R	Z	W	A	R	T	M	O	O	T	R	K
O	X	Q	A	D	E	I	H	P	R	Z	O	R
O	Q	A	R	W	O	C	C	A	B	O	T	N
D	S	E	D	E	L	D	G	M	R	F	R	O
S	Y	G	H	Y	U	I	J	I	K	I	A	I
T	X	P	T	C	C	L	V	N	J	B	N	T
R	N	E	I	M	A	R	T	E	Y	I	S	C
E	C	Q	W	O	Z	C	D	O	P	M	M	I
A	D	D	R	Y	C	T	A	R	E	N	I	D
M	O	T	K	Z	Q	P	O	N	A	T	T	D
N	E	T	T	E	R	A	G	I	C	W	T	A
G	E	U	N	I	C	O	T	I	N	E	E	L
A	L	S	G	N	I	K	O	M	S	I	R	R

EMPHYSEMA

NEUROTRANSMITTER

CIGAR

DOPAMINE

ADDICTION

REWARD

SMOKING

WITHDRAWAL

CIGARETTE

CANCER

DRUG

ACETYLCHOLINE

BRAIN

BLOODSTREAM

RECEPTOR

NICOTINE

TOBACCO





# Methamphetamine



## MECHANISM OF ACTION

### BACKGROUND

**Methamphetamine is an addictive drug that belongs to a class of drugs known as stimulants. This class also includes cocaine, caffeine, and other drugs.**

**Methamphetamine is made illegally with relatively inexpensive over-the-counter ingredients. Many of the ingredients that are used to produce methamphetamine, such as drain cleaner, battery acid, and antifreeze, are extremely dangerous. The rapid proliferation of "basement" laboratories for the production of methamphetamine has led to a widespread problem in many communities in the U.S.**

**Methamphetamine has many effects in the brain and body. Short-term effects can include increased wakefulness, increased physical activity, decreased appetite, increased respiration, hyperthermia, irritability, tremors, convulsions, and aggressiveness.**

**Hyperthermia and convulsions can result in death. Single doses of methamphetamine have also been shown to cause damage to nerve terminals in studies with animals. Long-term effects can include addiction, stroke, violent behavior, anxiety, confusion, paranoia, auditory hallucinations, mood disturbances, and delusions. Long-term use can also cause damage to dopamine neurons that persists long after the drug has been discontinued.**

Methamphetamine acts on the pleasure circuit in the brain by altering the levels of certain neurotransmitters present in the synapse. Chemically, methamphetamine is closely related to amphetamine, but its effects on the central nervous system are greater than those of amphetamine.

Methamphetamine is also chemically similar to dopamine and another neurotransmitter, norepinephrine. It produces its effects by causing dopamine and norepinephrine to be released into the synapse in several areas of the brain, including the nucleus accumbens, prefrontal cortex, and the striatum, a brain area involved in movement. Specifically, methamphetamine enters nerve terminals by passing directly through nerve cell membranes. It is also carried into the nerve terminals by transporter molecules that normally carry dopamine or norepinephrine from the synapse back into the nerve terminal. Once in the nerve terminal, methamphetamine enters dopamine and norepinephrine containing vesicles and causes the release of these neurotransmitters. Enzymes in the cell normally chew up excess dopamine and norepinephrine; however, methamphetamine blocks this breakdown. The excess neurotransmitters are then carried by transporter molecules out of the neuron and into the synapse. Once in the synapse, the high concentration of dopamine causes feelings of pleasure and euphoria. The excess norepinephrine may be responsible for the alertness and anti-fatigue effects of methamphetamine.

Methamphetamine can also affect the brain in other ways. For example, it can cause cerebral edema, brain hemorrhage, paranoia, and hallucinations. Some of the effects of methamphetamine on the brain may be long-lasting and even permanent. Recent research in humans has shown that even three years after chronic methamphetamine users have discontinued use of the drug there is still a reduction in their ability to transport dopamine back into neurons. This clearly demonstrates that there is a long-lasting impairment in

# Methamphetamine

dopamine function as a result of drug use. This is highly significant because dopamine has a major role in many brain functions, including experiences of pleasure, mood, and movement. In these same studies, researchers compared the damage to the dopamine system of methamphetamine users to that seen in patients with Parkinson's disease. Parkinson's disease is characterized by a progressive loss of dopamine neurons in brain regions that are involved in movement. Although the damage to the dopamine system was greater in the Parkinson's patients, the brains of former methamphetamine users showed similar patterns to that seen in Parkinson's disease. Scientists now believe that the damage to the dopamine system from long-term methamphetamine use may lead to symptoms of Parkinson's disease. (It should be noted that Parkinson's disease itself is not caused by drug use.) In support of this, research with laboratory animals has demonstrated that exposure to a single, high-dose of methamphetamine or prolonged exposure at low doses destroys up to fifty

percent of the dopamine-producing neurons in certain parts of the brain.

Methamphetamine also has widespread effects on other parts of the body. It can cause high blood pressure, arrhythmias, chest pain, shortness of breath, nausea, vomiting, and diarrhea. It can also increase body temperature, which can be lethal in overdose situations.

The following activities, when used along with the magazine on methamphetamine, will help explain to students how this substance changes the brain and the body.



# Methamphetamine



## OBJECTIVE

- ★ **The student will become more familiar with the neuroscience concepts and terminology associated with the effects of methamphetamine on the brain and body.**

## METHAMPHETAMINE ACTIVITY ONE

The students will complete the methamphetamine Word Search. The teacher will then review the words and have the students discuss how the terms relate to methamphetamine abuse. A copy of the Word Search and Word Search Solution is included in the guide.

## OBJECTIVE

- ★ **The student will become familiar with how methamphetamine changes brain functioning and the potential long-term implications of these changes.**

## METHAMPHETAMINE ACTIVITY TWO

Review the effects of methamphetamine on the brain, paying particular attention to its effects on the neurotransmitter dopamine. Have students break into small groups. Ask each group to write and perform a play that demonstrates how methamphetamine changes the normal functioning of neurons that contain dopamine. Discuss with students how these changes can result in long-term impairment of dopamine function and the implications of this impairment (e.g., inability to feel pleasure, symptoms of Parkinson's Disease).

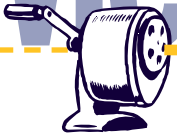
## OBJECTIVE

- ★ **The student will learn more about how methamphetamine and other drugs change the way the brain works.**

## METHAMPHETAMINE ACTIVITY THREE

Review with students the function of various brain areas (e.g., amygdala, hippocampus, cerebellum, etc.). Have students break into small groups and assign each group one brain area. Ask the students to discuss how methamphetamine or other drugs might affect their brain area. Then have students discuss the function of this brain area and how changing it through drug use might change how a person feels, acts, remembers, learns, etc. Have each group present a summary of their discussions to the entire class. For extra credit, have students discuss and present how brain imaging techniques (such as PET, or Positron Emission Tomography) help researchers to examine how drugs act in the brains of living human subjects.

# Methamphetamine



## WORD SEARCH

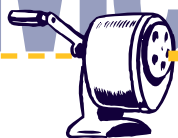
M	N	R	O	E	T	T	N	A	L	U	M	I	T	S
F	E	O	L	A	Q	P	N	Z	L	N	O	N	T	N
E	U	T	G	N	S	O	F	T	E	I	O	J	U	O
P	R	P	H	I	X	R	O	U	M	N	Y	E	G	I
W	O	E	L	A	J	E	R	E	I	O	K	C	A	T
Q	T	C	T	R	M	O	S	N	H	T	R	T	W	A
U	R	E	A	B	N	P	O	I	D	O	A	E	S	N
P	A	R	V	A	A	A	H	O	I	R	S	D	M	I
M	N	Y	Z	N	L	R	P	E	D	E	E	P	S	C
F	S	O	Y	E	O	A	L	A	T	S	Y	R	C	U
E	M	S	B	U	M	N	I	R	K	A	V	T	I	L
T	I	L	T	I	I	O	N	T	L	P	M	U	U	L
G	T	G	N	R	T	I	C	E	A	G	G	I	S	A
B	T	E	P	O	O	A	S	I	H	V	U	B	N	H
J	E	F	E	N	P	K	W	H	C	X	R	Q	B	E
C	R	A	S	H	N	I	E	T	I	R	D	N	E	D

Methamphetamine  
Crystal  
Speed  
Paranoia  
Dopamine  
Synapse  
Stimulant  
Brain

Neurotransmitter  
Axon  
Receptor  
Crash  
Hallucinations  
Serotonin  
PET

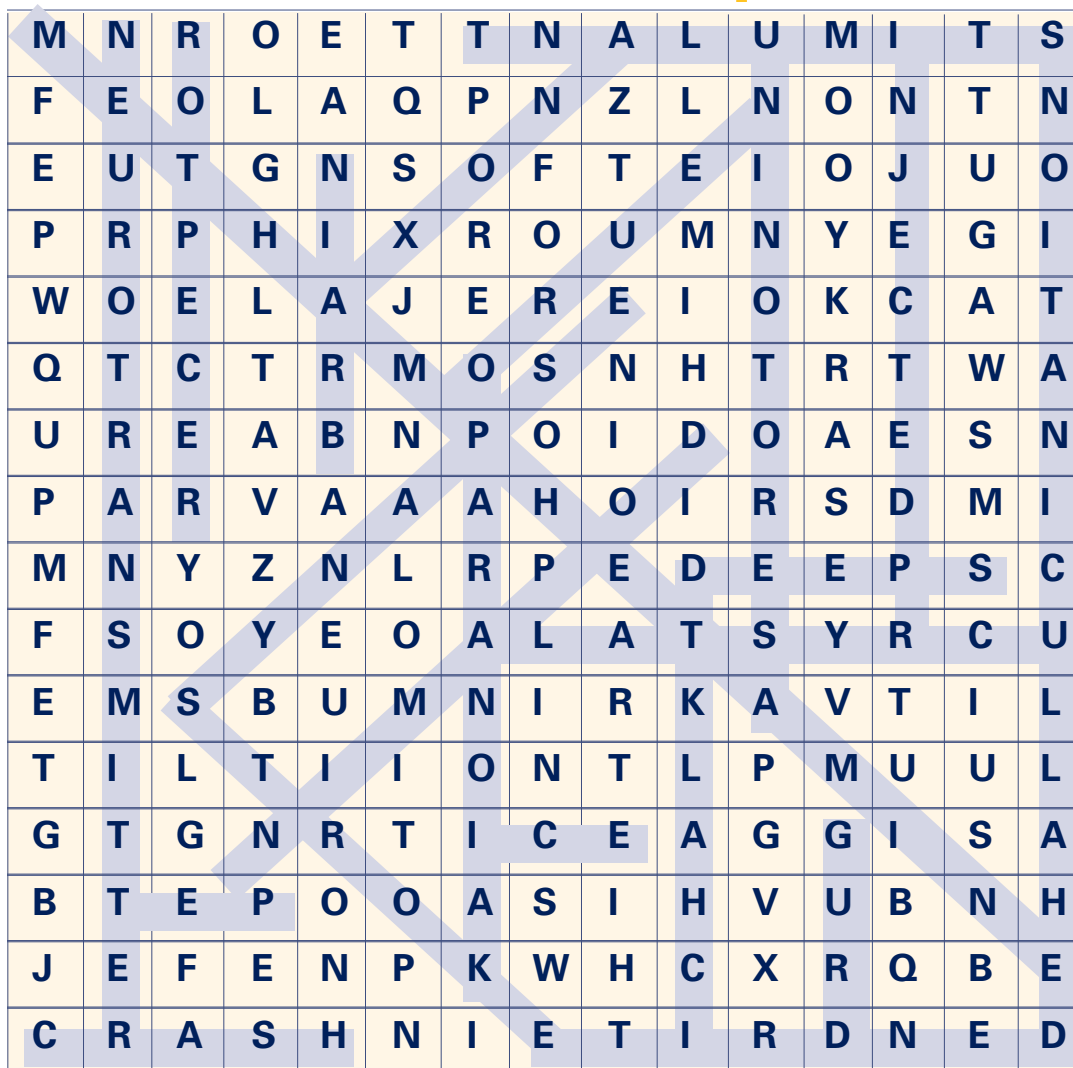
Neuron  
Stroke  
Dendrite  
Drug  
Ice  
Chalk  
Injected

# Methamphetamine



## WORD SEARCH

SOLUTION



42

Methamphetamine  
Crystal  
Speed  
Paranoia  
Dopamine  
Synapse  
Stimulant  
Brain

Neurotransmitter  
Axon  
Receptor  
Crash  
Hallucinations  
Serotonin  
PET

Neuron  
Stroke  
Dendrite  
Drug  
Ice  
Chalk  
Injected



# General

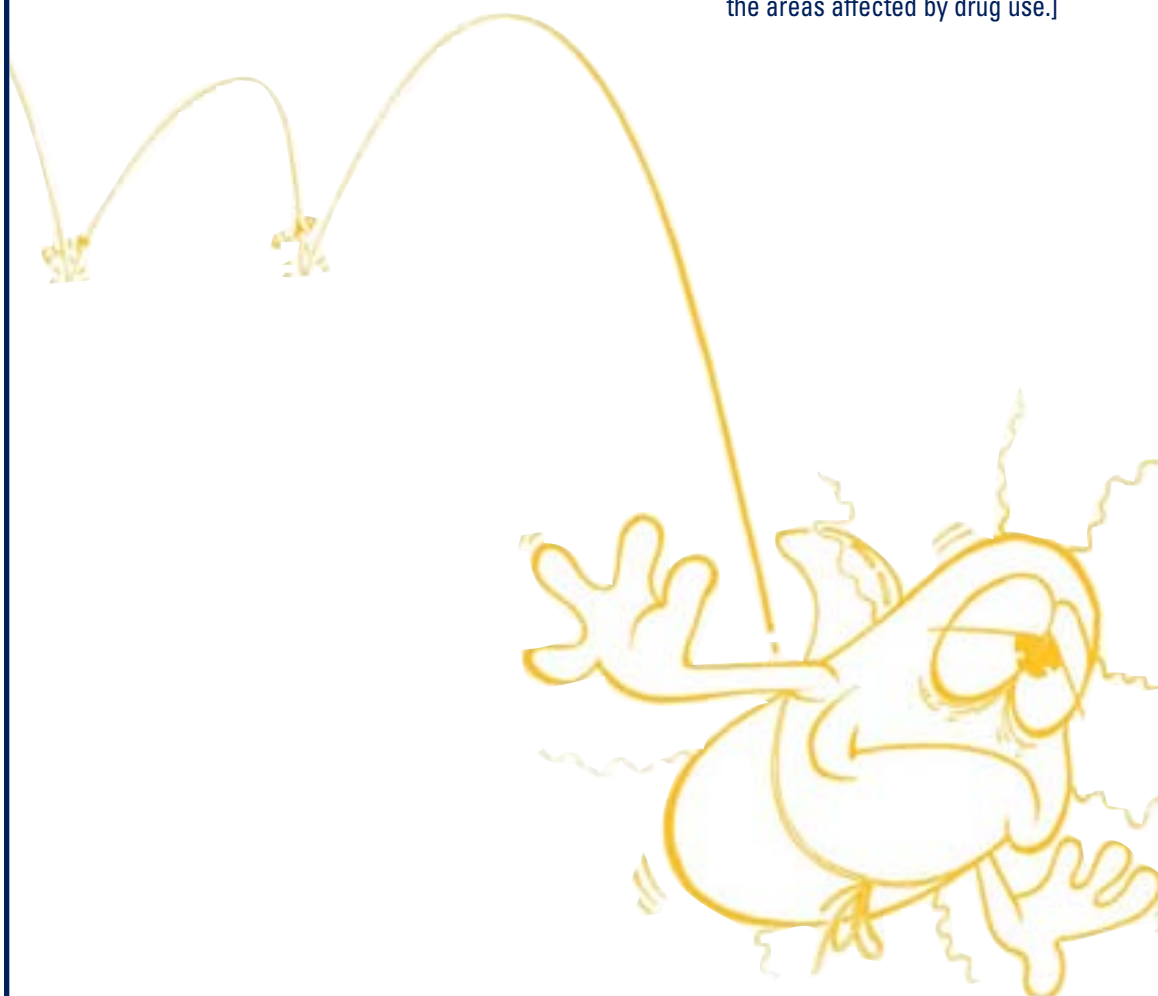


## OBJECTIVES

- ★ **The student will learn the names of the lobes, cortical areas, and structures in the brain.**
- ★ **The student will learn the specific brain areas and structures affected by drug use.**

## UNIFYING ACTIVITY

Students will use reference materials to create three brain maps: one which shows the different regions of the brain, one which shows the areas within the cortex, and one which displays different brain structures. For all of the drugs discussed, students will “mark” their maps (for example, using stickers or colored markers) to specify the areas affected by substance use. [Note: If materials such as molding clay or plaster are available, have groups of students also create three-dimensional brain models, and use small, separate strands of Christmas lights to “mark” the areas affected by drug use.]





# Resources

## **National Institute on Drug Abuse**

301-443-6245

<http://www.drugabuse.gov>

## **National Clearinghouse for Alcohol and Drug Information**

1-800-729-6686 or 1-800-487-4889 (TDD)

<http://www.health.org>

## **Office of Science Education**

### **National Institutes of Health**

301-402-2828

## **Society for Neuroscience**

### **Education Program**

202-462-6688

<http://www.sfn.org>

## **Society for Neuroscience Brain Briefings**

<http://www.sfn.org/briefings>

This site provides access to Society for Neuroscience publications covering topics such as addiction, opiate receptors, and the effects of various drugs on the brain and behavior.

## **Society for Neuroscience Brain Backgrounders**

<http://www.sfn.org/backgrounders/>

This site provides an online series of articles that answer basic neuroscience questions.

## **National Families in Action Online**

<http://www.nationalfamilies.org>

This site includes the latest scientific information about the effects of drugs on the brain and body, and allows the visitor to ask neuroscience experts questions about drugs.

## **Neurosciences on the Internet**

<http://www.neuroguide.com>

This site includes information on basic neurosciences, including recent journal articles that discuss drugs of abuse.

## **Wisconsin/Michigan State Brain Collections**

<http://www.neurophys.wisc.edu>

This site includes a visual tour of photos and brain sections of mammalian brains, with related information on brain anatomy, brain functions, and neuroanatomy.

## **Eisenhower National Clearinghouse**

<http://www.enc.org/>

This site provides a source of published materials for K-12 math and science teachers.

## **Brain Anatomy**

<http://www.exploratorium.edu/memory/braindissection/index.html>

This site provides images of a sheep brain dissection.

## **Science in the News**

<http://whyfiles.org/>

This site provides articles on science items that have been in the news. Several articles on nicotine addiction can be found through the Search button.

## Internet Sites

## **National Institute on Drug Abuse**

<http://www.drugabuse.gov>

<http://teens.drugabuse.gov>

This site contains information on drugs of abuse, NIDA publications and communications, agency events, and links to other drug-related Internet sites.

## **Sara's Quest**

<http://www.sarasquest.org>

Join Sara Bellum as she explores how drugs affect the brain. This site features questions related to the Mind Over Matter materials. Students can join Sara's Quest Club and receive a free poster.

## **National Clearinghouse for Alcohol and Drug Information**

<http://www.health.org>

This site includes information on publications, calendars, and related Internet sites, as well as a youth site.

## **Office of Science Education**

### **National Institutes of Health**

<http://science-education.nih.gov>

This site provides a "one-stop shopping service" for people looking for information from the National Institutes of Health. It contains sections for teachers, students, and the public.

## **Neuroscience for Kids**

<http://faculty.washington.edu/chudler/introb.html>

This site includes answers to commonly asked questions about the brain and neuroscience, with information on brain and spinal cord anatomy and physiology, neurotransmission, and the effects of specific drugs on the nervous system.

## **Dana Alliance for Brain Initiatives**

<http://www.dana.org/brainweb>

This site includes resources for people interested in brain diseases and disorders, with specific sections devoted to alcohol and drug abuse.



# Reading List

**Brain Facts: A primer on the Brain and Nervous System, Society for Neuroscience, 1993.**

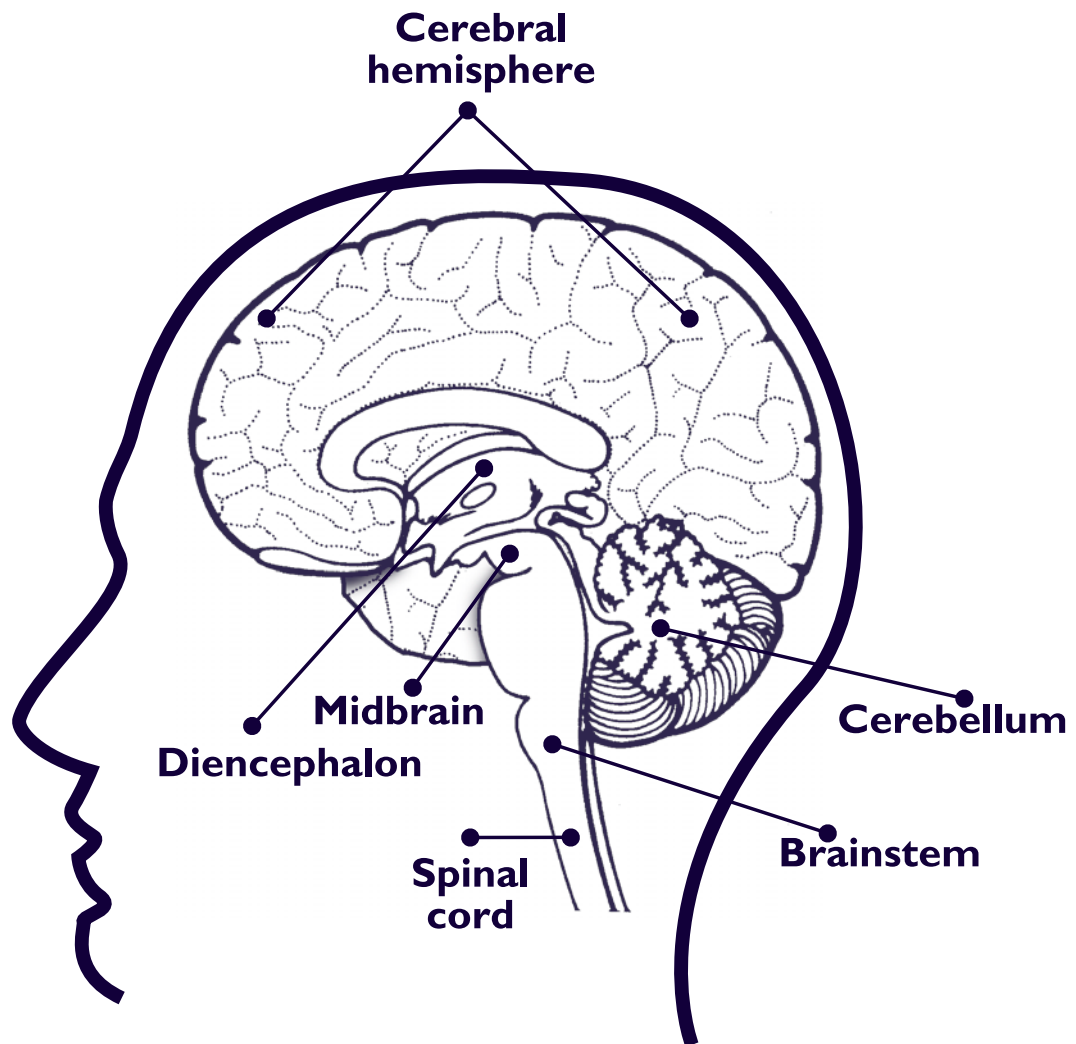
**How your Brain Works, by Anne D. Novitt-Morino, M.D., Ziff-Davis Press, 1995.**

**Explorations in Neuroscience for Children and Adults, Baylor College of Medicine, WOW Publications, Inc., 1997.**

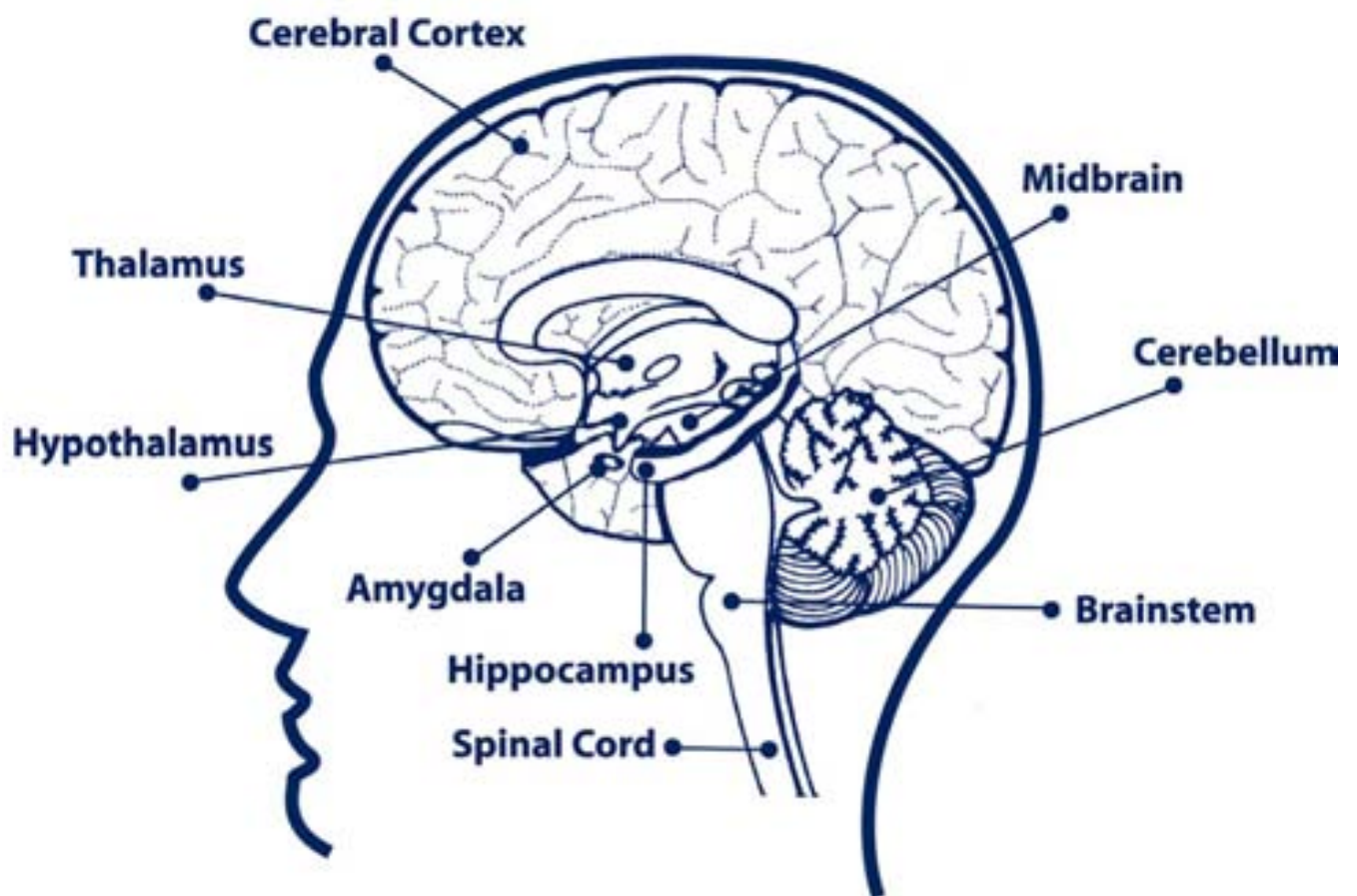




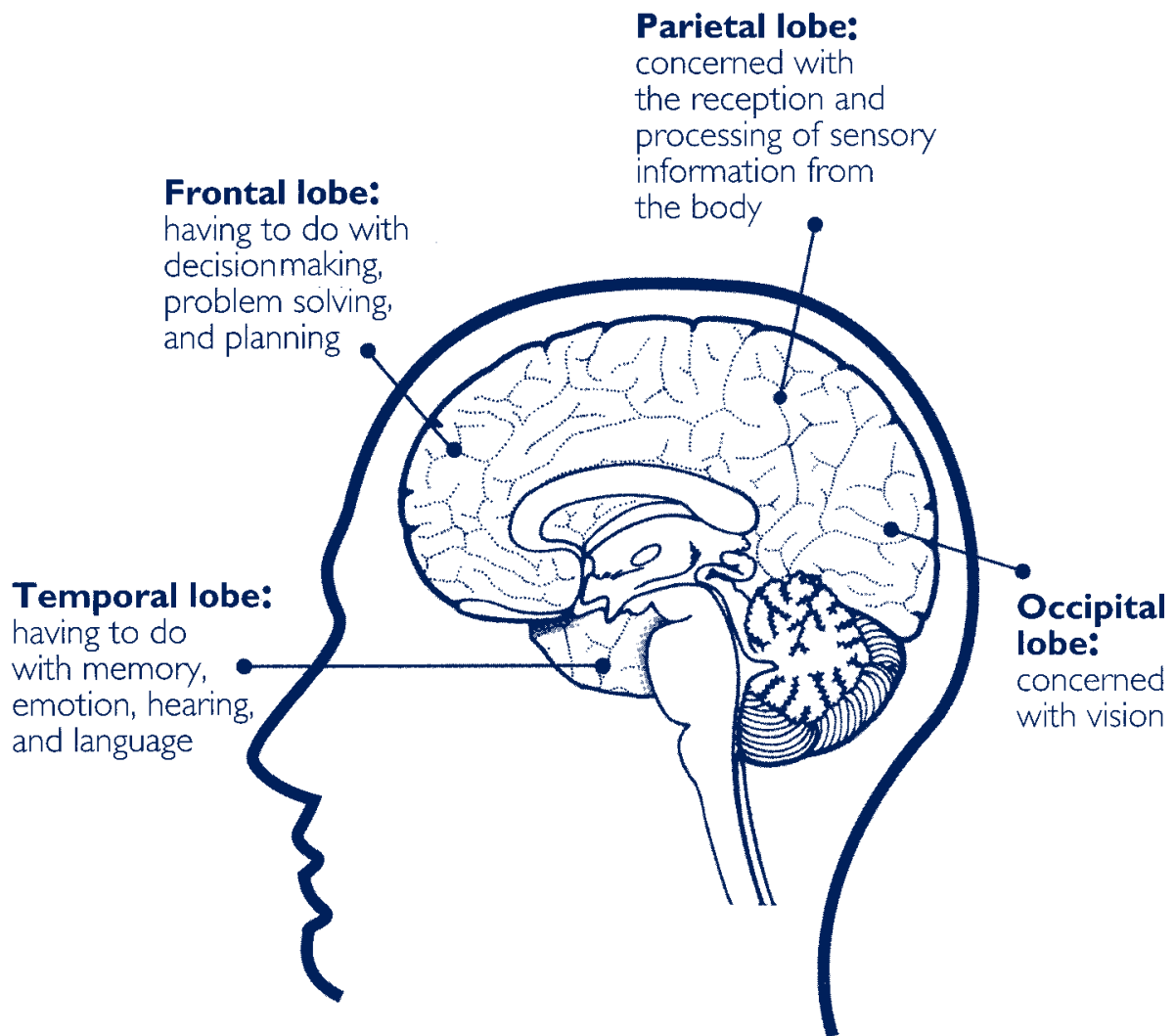
**Figure 1**



**Figure 2**

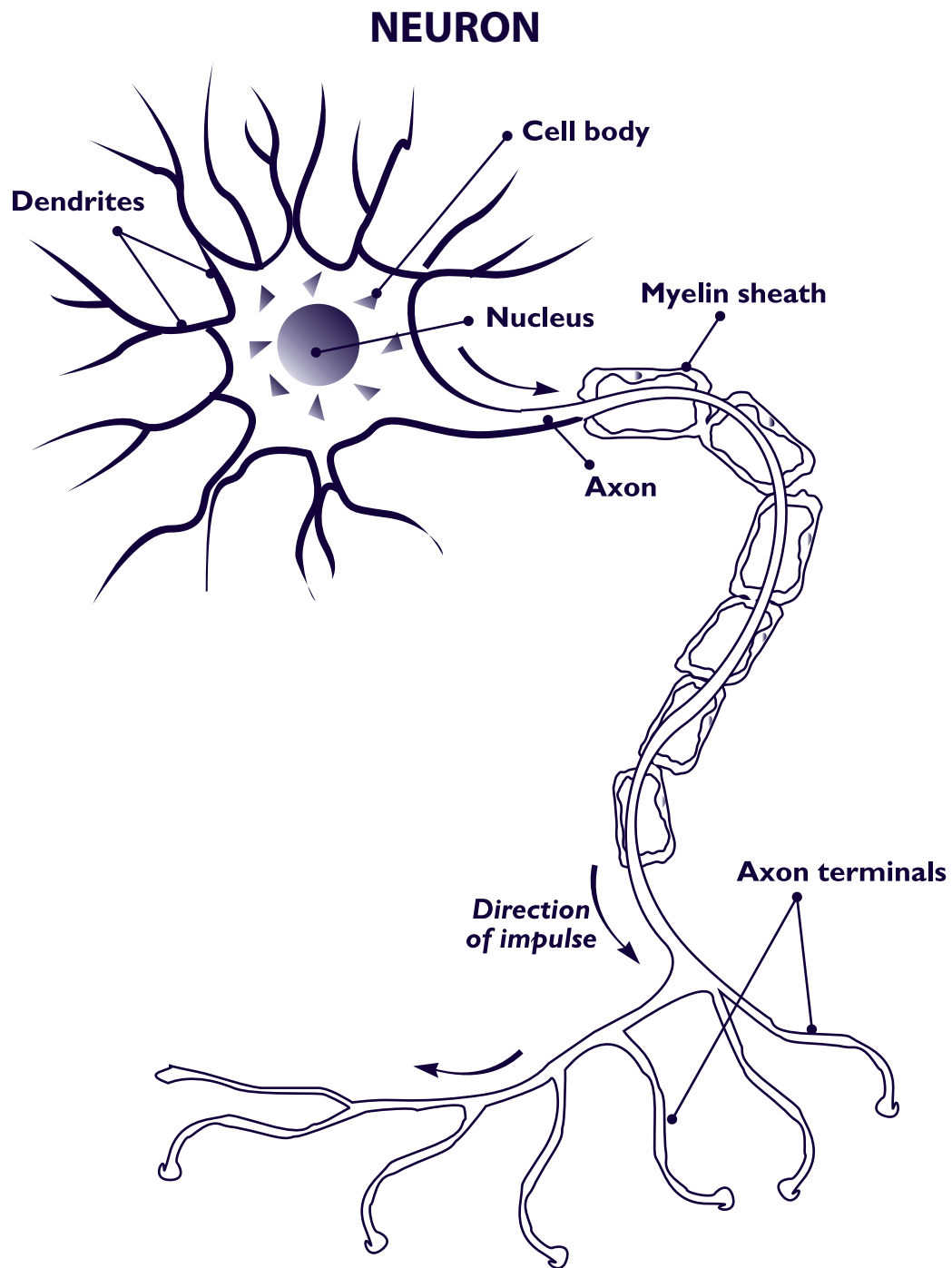


# Figure 3

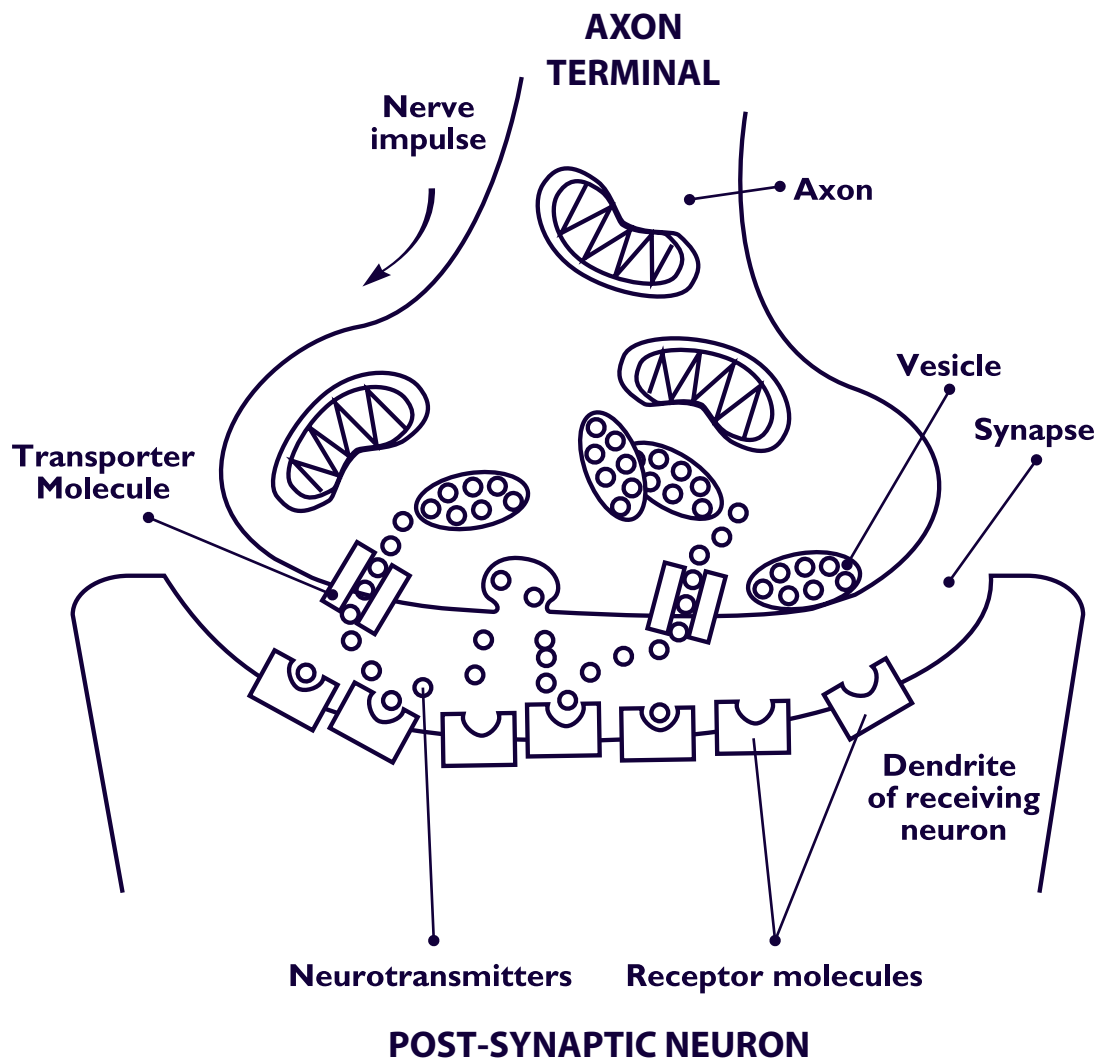




**Figure 4**

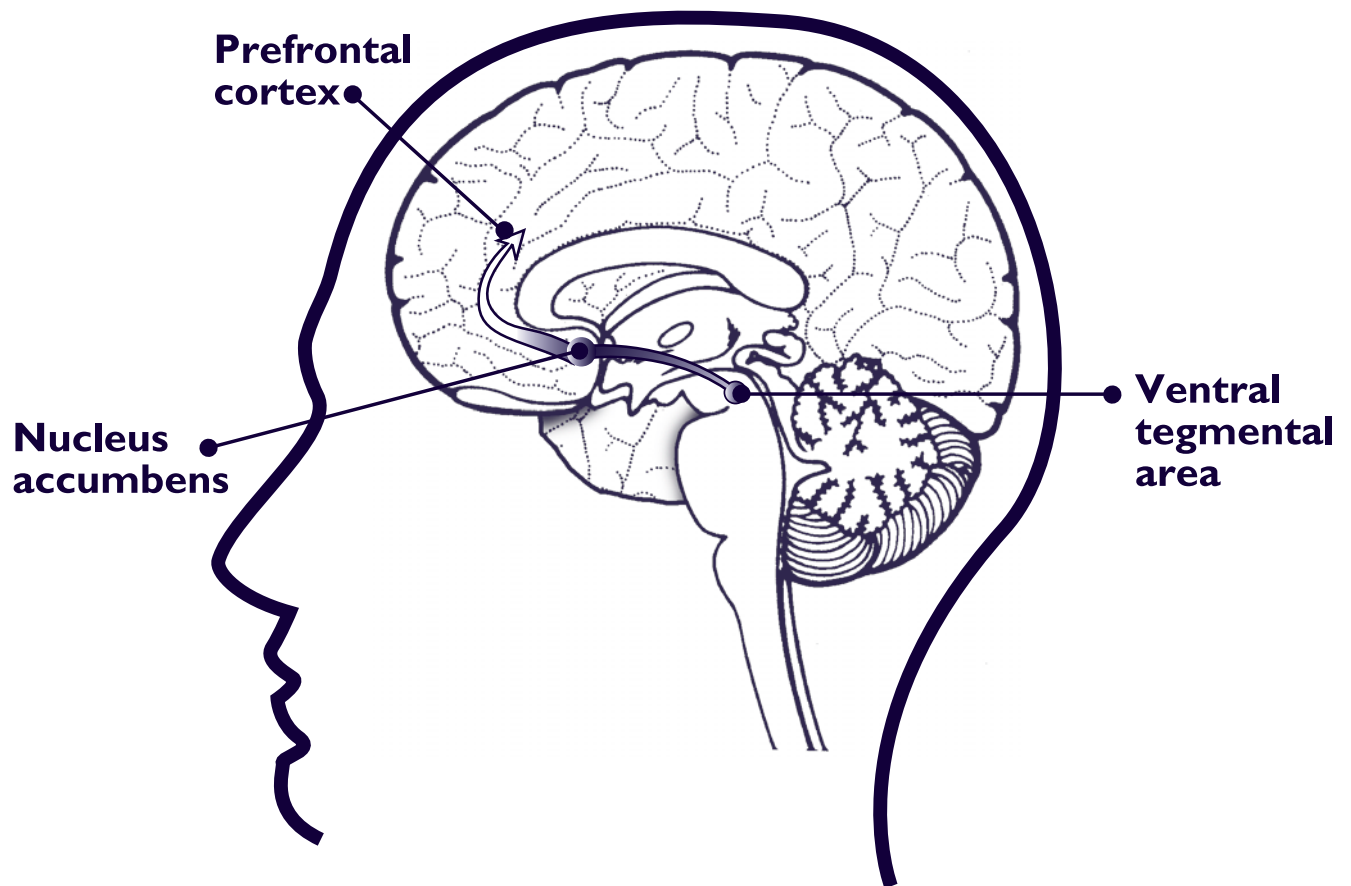


**Figure 5**

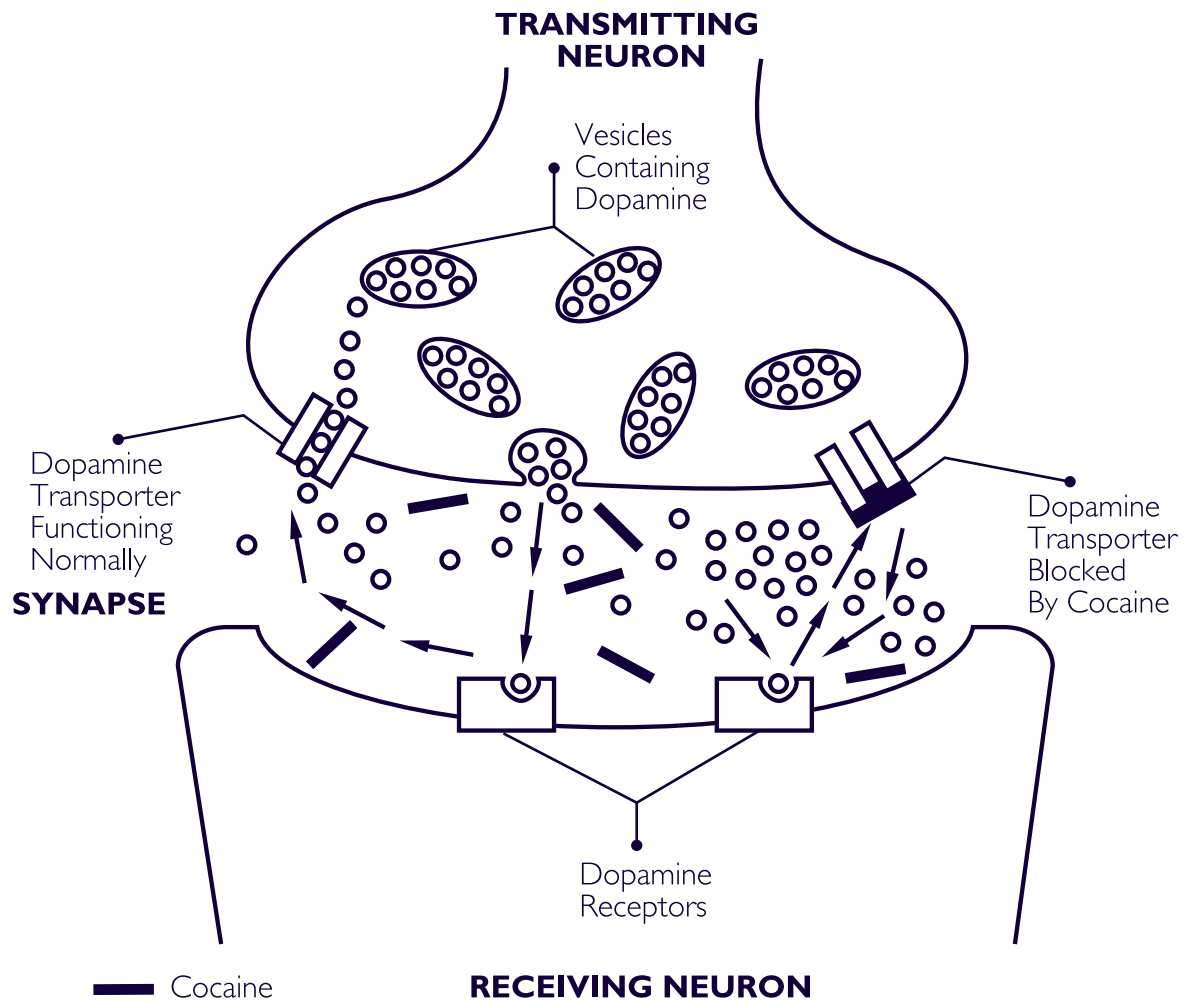


**Figure 6**

**REWARD CIRCUIT**



**Figure 7**





**[www.sarasquest.org](http://www.sarasquest.org)**

This site features questions related to the Mind Over Matter materials. Students can join Sara's Quest Club and receive free posters.



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# The Brain's Response to Drugs Teacher's Guide

— Revision —

**NIDA**  
NATIONAL INSTITUTE  
ON DRUG ABUSE



*Come Lead  
My  
Exploration  
Team*





# Mind Over Matter



## TEACHER'S GUIDE

i

U.S. Department of Health and Human Services  
National Institutes of Health  
National Institute on Drug Abuse  
Office of Science Policy and Communications  
Science Policy Branch  
6001 Executive Boulevard, Room 5230 MSC 9591  
Bethesda, Maryland 20892



## "MIND OVER MATTER" TEACHER'S GUIDE

"Mind Over Matter" was produced under contract No. NO1 DA-3-2401 for the Office of Science Policy and Communications, National Institutes of Health. Cathrine A. Sasek, Ph.D. served as scientific advisor and Project Officer. All materials in the "Mind Over Matter" series are in the public domain and may be reproduced without permission. Citation of the source is appreciated.

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Additional copies, as well as other drug related publications, can be obtained through the National Clearinghouse for Alcohol and Drug Information at 1-800-729-6686 or at [www.teens.drugabuse.gov](http://www.teens.drugabuse.gov).

The U.S. Government does not endorse or favor any specific commercial product or company. Trade, proprietary, or company names appearing in this publication are used only because they are considered essential in the context of the studies reported herein.

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# Introduction



## "MIND OVER MATTER" TEACHER'S GUIDE

This is the teacher's guide for the "Mind Over Matter" series. This exciting neuroscience education series, developed by the National Institute on Drug Abuse (NIDA), a component of the National Institutes of Health, is designed to encourage youngsters in grades 5-9 to learn about the biological effects of drug abuse on the body and the brain.

The "Mind Over Matter" series includes eight colorful, glossy magazines, each of which is devoted to a specific drug or drug group; including stimulants, hallucinogens, inhalants, marijuana, opiates, nicotine, methamphetamine, and steroids. Each of the magazines describes the effects of specific drugs or drug types on the anatomy and physiology of the brain and the body. These educational materials further elaborate on the way in which these drug-induced changes affect both behaviors and emotions.

The background information and lesson plans contained in this guide, when used in combination with the magazines in the series, will promote an understanding of the physical reality of drug use, as well as curiosity about neuroscience. The guide suggests a brain anatomy educational activity that can be used throughout the curriculum (see page 43), as well as additional activities for each of the six drug topics. Of course, you are encouraged to develop your own relevant lesson plans.

**Note:** Full-size versions of Figures 1-7 are located in the back of this guide.

# Background

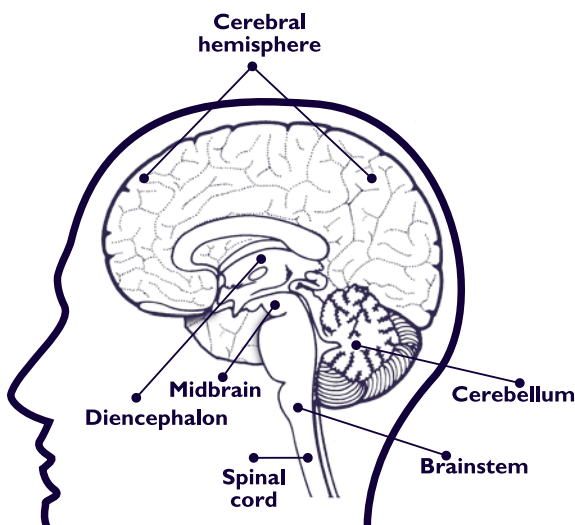
## BRAIN ANATOMY

The brain consists of several large regions, each responsible for some of the activities vital for living. These include the brainstem, cerebellum, limbic system, diencephalon, and cerebral cortex (Figures 1 and 2).

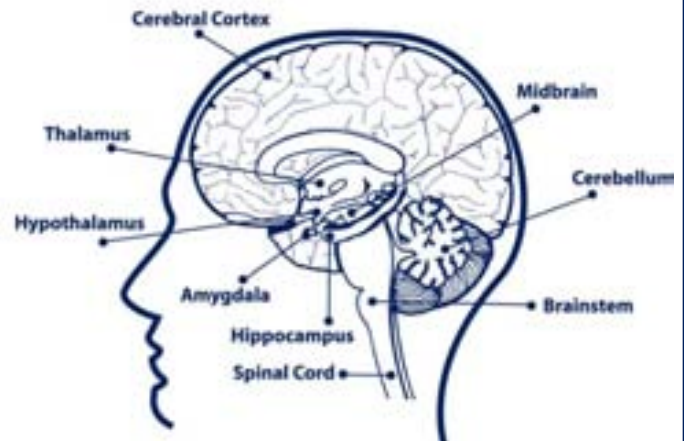
The brainstem is the part of the brain that connects the brain and the spinal cord. It controls many basic functions, such as heart rate, breathing, eating, and sleeping. The brainstem accomplishes this by directing the spinal cord, other parts of the brain, and the body to do what is necessary to maintain these basic functions.

The cerebellum, which represents only one-eighth of the total weight of the human brain, coordinates the brain's instructions for skilled repetitive movements and for maintaining balance and posture. It is a prominent structure located above the brainstem.

On top of the brainstem and buried under the cortex, there is a set of more evolutionarily primitive brain structures called the limbic system (e.g., amygdala and hippocampus, as in Figure 2). The limbic system structures are involved in many of



**FIGURE 1** This drawing of a brain cut in half demonstrates some of the major regions of the brain.



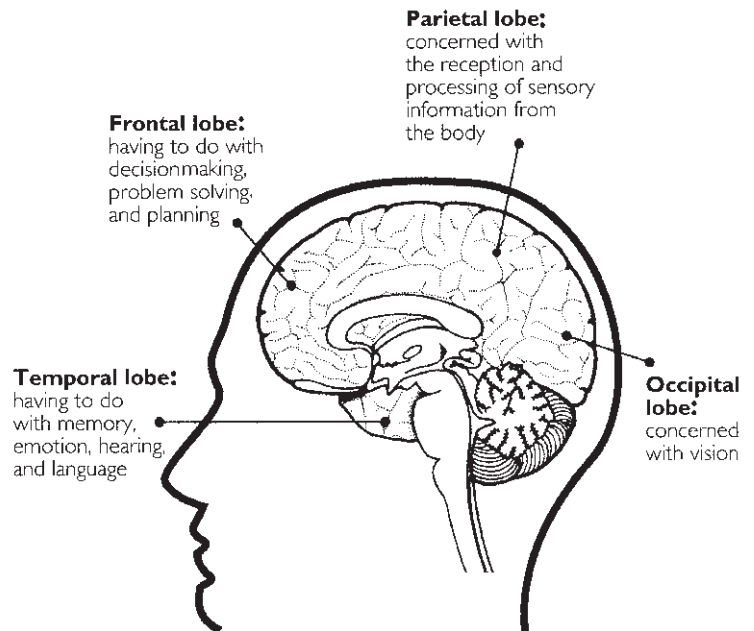
**FIGURE 2** This drawing of a brain cut in half demonstrates some of the brain's internal structures. The amygdala and hippocampus are actually located deep within the brain, but are shown as an overlay in the approximate areas that they are located.

our emotions and motivations, particularly those that are related to survival, such as fear, anger, and sexual behavior. The limbic system is also involved in feelings of pleasure that are related to our survival, such as those experienced from eating and sex. The large limbic system structure, the hippocampus, is also involved in memory. One of the reasons that drugs of abuse can exert such powerful control over our behavior is that they act directly on the more evolutionarily primitive brainstem and limbic system structures, which can override the cortex in controlling our behavior. In effect, they eliminate the most human part of our brain from its role in controlling our behavior.

The diencephalon, which is also located beneath the cerebral hemispheres, contains the thalamus and hypothalamus (Figure 2). The thalamus is involved in sensory perception and regulation of motor functions (i.e., movement). It connects areas of the cerebral cortex that are involved in sensory perception and movement with other parts of the brain and spinal cord that also have a role in sensation and movement. The hypothalamus

is a very small but important component of the diencephalon. It plays a major role in regulating feeding hormones, the pituitary gland, body temperature, the adrenal glands, and many other vital activities.

The cerebral cortex, which is divided into right and left hemispheres, encompasses about two-thirds of the human brain mass and lies over and around most of the remaining structures of the brain. It is the most highly developed part of the human brain and is responsible for thinking, perceiving, and producing and understanding language. It is also the most recent structure in the history of brain evolution. The cerebral cortex can be divided into areas that each have a specific function (Figure 3). For example, there are specific areas involved in vision, hearing, touch, movement, and smell. Other areas are critical for thinking and reasoning. Although many functions, such as touch,



**FIGURE 3** This drawing of a brain cut in half demonstrates the lobes of the cerebral cortex and their functions.

are found in both the right and left cerebral hemispheres, some functions are found in only one cerebral hemisphere. For example, in most people, language abilities are found in the left hemisphere.

## NERVE CELLS AND NEUROTRANSMISSION

3

The brain is made up of billions of nerve cells, also known as neurons. Typically, a neuron contains three important parts (Figure 4): a central cell body that directs all activities of the neuron; dendrites, short fibers that receive messages from other neurons and relay them to the cell body; and an axon, a long single fiber that transmits messages from the cell body to the dendrites of other neurons or to body tissues, such as muscles. Although most neurons contain all of the three parts, there is a wide range of diversity in the shapes and sizes of neurons as well as their axons and dendrites.

The transfer of a message from the axon of one nerve cell to the dendrites of another is known as neurotransmission. Although axons and dendrites are located extremely close to each other, the transmission of a message from an axon to a dendrite does not occur through

direct contact. Instead, communication between nerve cells occurs mainly through the release of chemical substances into the space between the axon and dendrites (Figure 5). This space is known as the synapse. When neurons communicate, a message, traveling as an electrical impulse, moves down an axon and toward the synapse. There it triggers the release of molecules called neurotransmitters from the axon into the synapse. The neurotransmitters then diffuse across the synapse and bind to special molecules, called receptors, that are located within the cell membranes of the dendrites of the adjacent nerve cell. This, in turn, stimulates or inhibits an electrical response in the receiving neuron's dendrites. Thus, the neurotransmitters act as chemical messengers, carrying information from one neuron to another.



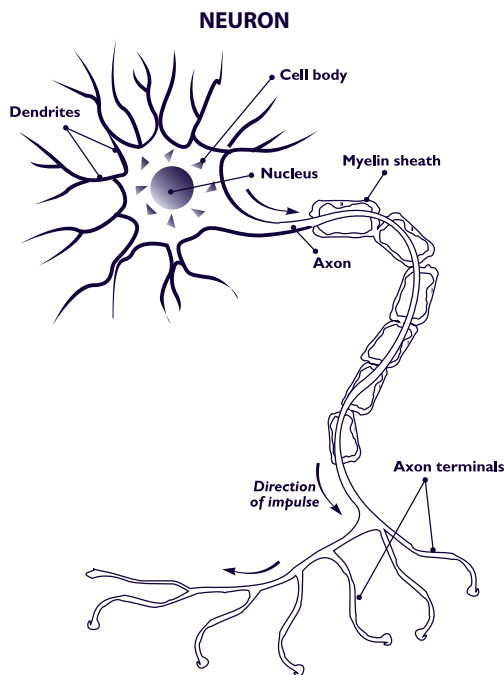


FIGURE 4

There are many different types of neurotransmitters, each of which has a precise role to play in the functioning of the brain. Generally, each neurotransmitter can only bind to a very specific matching receptor. Therefore, when a neurotransmitter couples to a receptor, it is like fitting a key into a lock. This coupling then starts a whole cascade of events at both the surface of the dendrite of the receiving nerve cell and inside the cell. In this manner, the message carried by the neurotransmitter is received and processed by the receiving nerve cell. Once this has occurred, the neurotransmitter is inactivated in one of two ways. It is either broken down by an enzyme or reabsorbed back into the nerve cell that released it. The reabsorption (also known as re-uptake) is accomplished by what are known as transporter molecules (Figure 5). Transporter molecules reside in the cell membranes of the axons that release the neurotransmitters. They pick up specific neurotransmitters from the synapse and carry them back across the cell membrane and into the axon. The neurotransmitters are then available for reuse at a later time.

As noted above, messages that are received by dendrites are relayed to the cell body and then to the axon. The axons then transmit the messages, which are in the form of electrical impulses, to other neurons or body tissues. The axons of many neurons are covered in a fatty substance known as myelin. Myelin has several functions. One of its most important is to increase the rate at which nerve impulses travel along the axon. The rate of conduction of a nerve impulse along a heavily myelinated axon can be as fast as 120 meters/second. In contrast, a nerve impulse can travel no faster than about 2 meters/second along an axon without myelin. The thickness of the myelin covering on an axon is closely linked to the function of that axon. For example, axons that travel a long distance, such as those that extend from the spinal cord to the foot, generally contain a thick myelin covering to facilitate faster transmission of the nerve impulse. (Note: The axons that transmit messages from the brain or spinal cord to muscles and other body tissues are what make up the nerves of the human body. Most of these axons contain a thick covering of myelin, which accounts for the whitish appearance of nerves.)

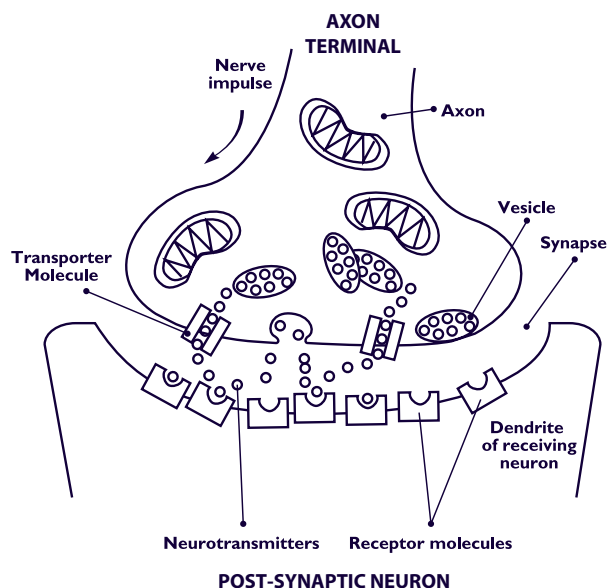
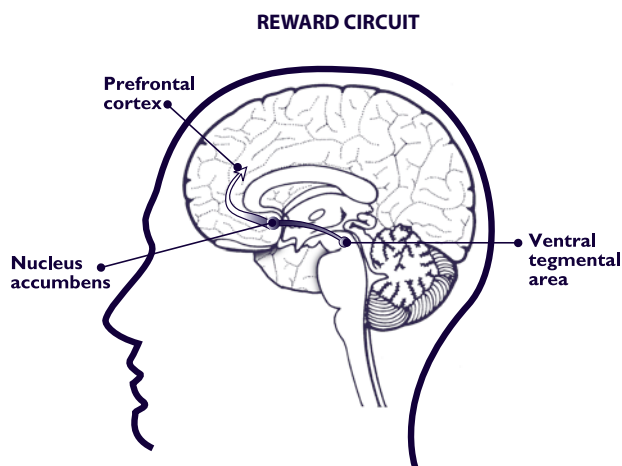


FIGURE 5

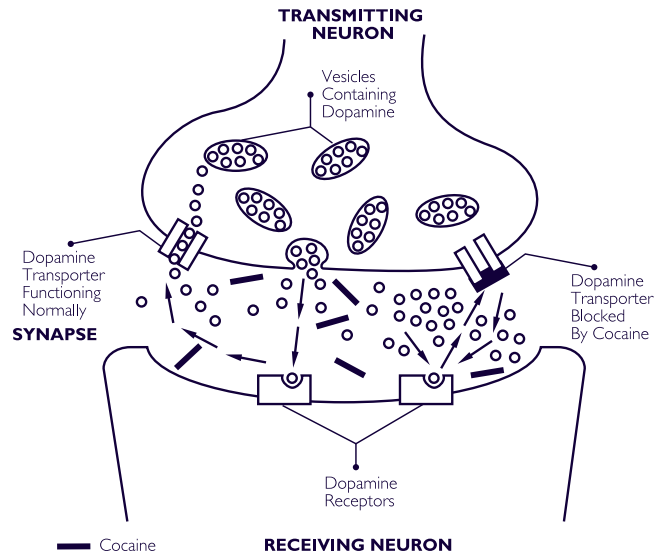
## EFFECTS OF DRUGS OF ABUSE ON THE BRAIN

Pleasure, which scientists call reward, is a very powerful biological force for our survival. If you do something pleasurable, the brain is wired in such a way that you tend to do it again. Life-sustaining activities, such as eating, activate a circuit of specialized nerve cells devoted to producing and regulating pleasure. One important set of these nerve cells, which uses a chemical neurotransmitter called dopamine, sits at the very top of the brainstem in the ventral tegmental area (VTA) (Figure 6). These dopamine-containing neurons relay messages about pleasure through their nerve fibers to nerve cells in a limbic system structure called the nucleus accumbens. Still other fibers reach to a related part of the frontal region of the cerebral cortex. So, the pleasure circuit, which is known as the mesolimbic dopamine system, spans the survival-oriented brainstem, the emotional limbic system, and the frontal cerebral cortex.

All drugs that are addicting can activate the brain's pleasure circuit. Drug addiction is a biological, pathological process that alters the way



**FIGURE 6** This drawing of a brain cut in half demonstrates the brain areas and pathways involved in the pleasure circuit.

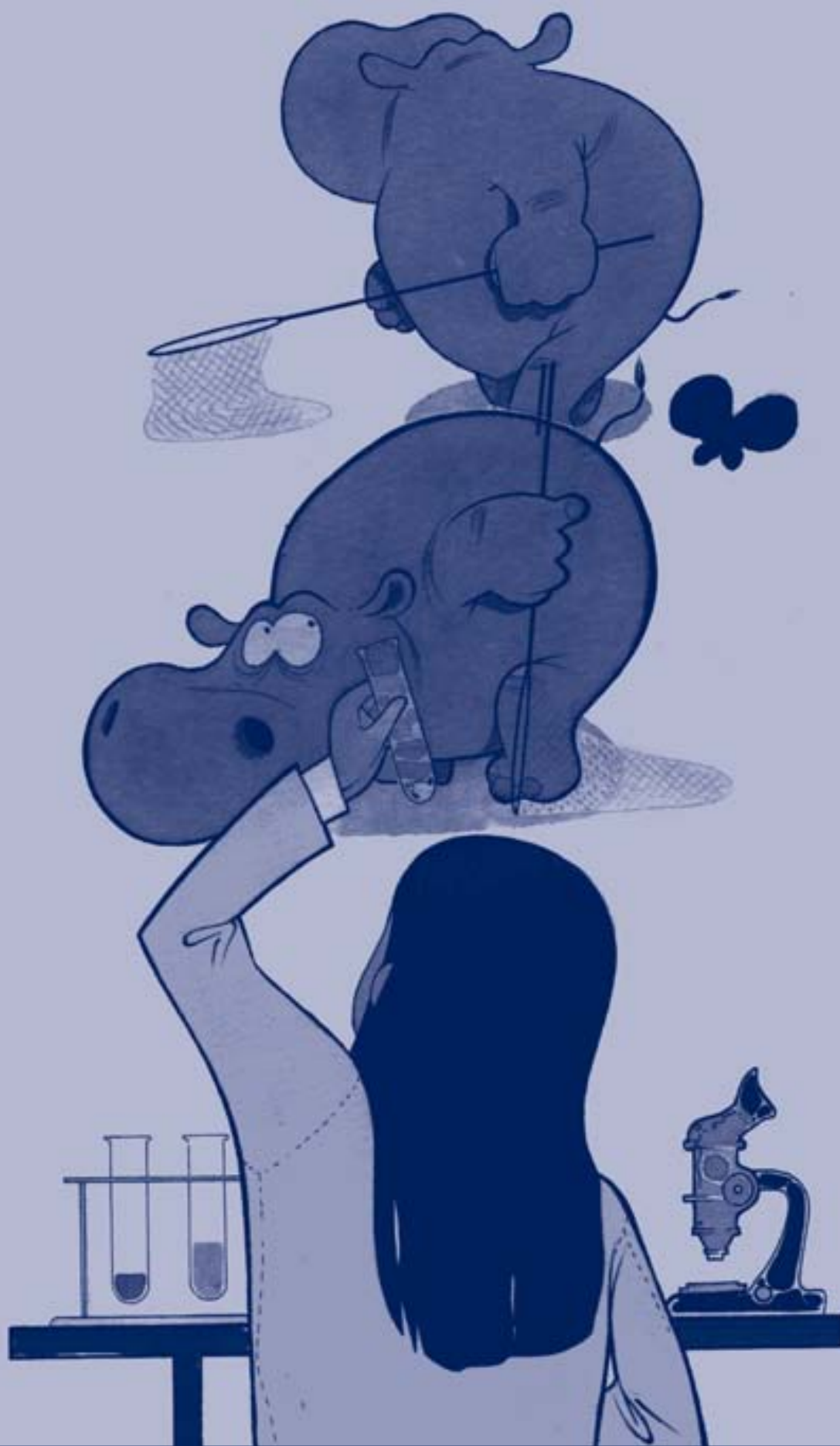


**FIGURE 7** When cocaine enters the brain, it blocks the dopamine transporter from pumping dopamine back into the transmitting neuron, flooding the synapse with dopamine. This intensifies and prolongs the stimulation of receiving neurons in the brain's pleasure circuits, causing a cocaine "high."

in which the pleasure center, as well as other parts of the brain, functions. To understand this process, it is necessary to examine the effects of drugs on neurotransmission. Almost all drugs that change the way the brain works do so by affecting chemical neurotransmission. Some drugs, like heroin and LSD, mimic the effects of a natural neurotransmitter. Others, like PCP, block receptors and thereby prevent neuronal messages from getting through. Still others, like cocaine, interfere with the molecules that are responsible for transporting neurotransmitters back into the neurons that released them (Figure 7). Finally, some drugs, such as methamphetamine, act by causing neurotransmitters to be released in greater amounts than normal.

Prolonged drug use changes the brain in fundamental and long-lasting ways. These long-lasting changes are a major component of the addiction itself. It is as though there is a figurative "switch" in the brain that "flips" at some point during an individual's drug use. The point at which this "flip" occurs varies from individual to individual, but the effect of this change is the transformation of a drug abuser to a drug addict.





# Marijuana



## MECHANISM OF ACTION

### BACKGROUND

**Marijuana is the dried leaves and flowers of the cannabis plant. Tetrahydrocannabinol (THC) is the main ingredient in marijuana that causes people who use it to experience a calm euphoria. Marijuana changes brain messages that affect sensory perception and coordination. This can cause users to see, hear, and feel stimuli differently and to exhibit slower reflexes.**

THC, the main active ingredient in marijuana, binds to and activates specific receptors, known as cannabinoid receptors. There are many of these receptors in parts of the brain that control memory, thought, concentration, time and depth perception, and coordinated movement.

By activating these receptors, THC interferes with the normal functioning of the cerebellum, the part of the brain most responsible for balance, posture, and coordination of movement. The cerebellum coordinates the muscle movements ordered by the motor cortex. Nerve impulses alert the cerebellum that the motor cortex has directed a part of the body to perform a certain action. Almost instantly, impulses from that part of the body inform the cerebellum as to how the action is being carried out. The cerebellum compares the actual movement with the intended movement and then signals the motor cortex to make any necessary corrections. In this way, the cerebellum ensures that the body moves smoothly and efficiently.

The hippocampus, which is involved with memory formation, also contains many cannabinoid receptors. Studies have suggested that marijuana activates cannabinoid receptors in the hippocampus and affects memory by decreasing the activity of neurons in this area. The effect of marijuana on long-term memory is less certain, but while someone is under the influence of marijuana, short-term memory can be compromised. Further, research studies have shown chronic administration of THC can permanently damage the hippocampus of rats, suggesting that marijuana use can lead to permanent memory impairment.

# Marijuana

8

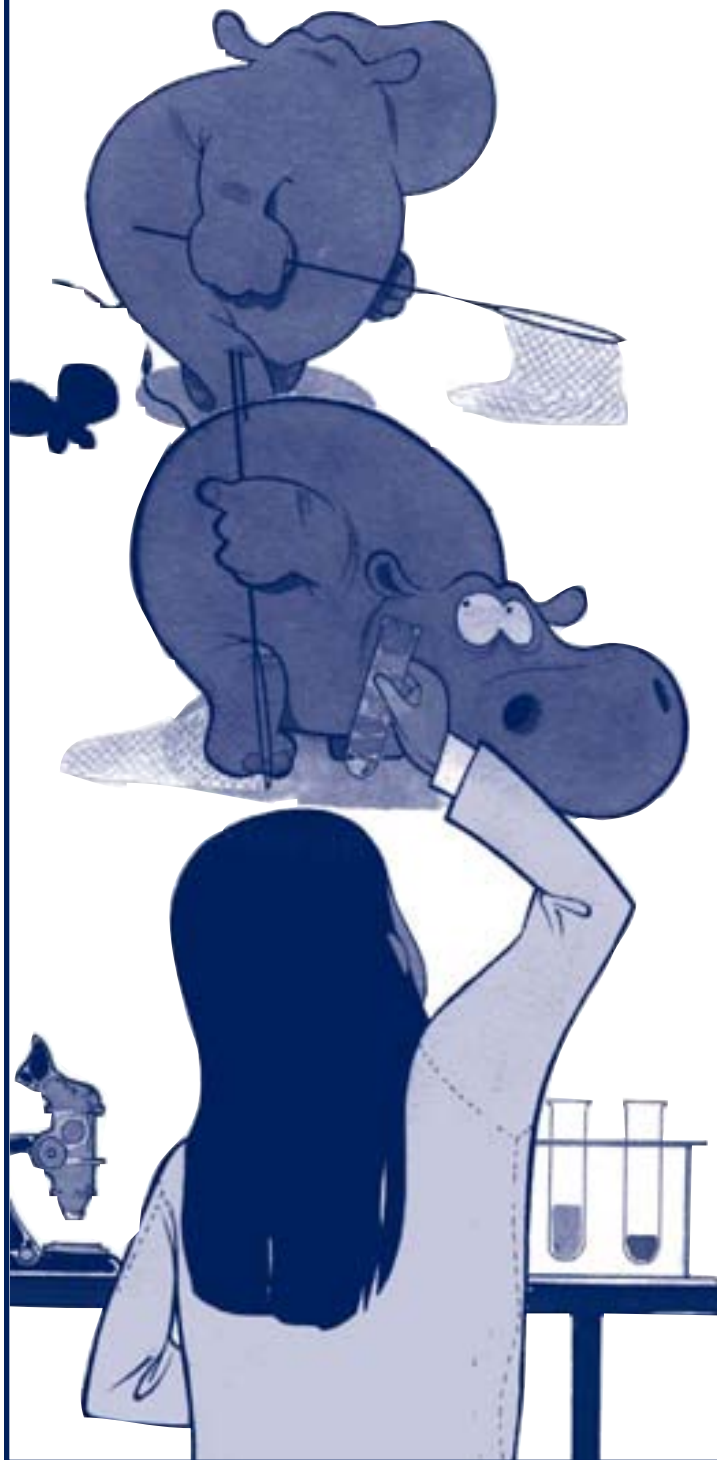
Marijuana also affects receptors in brain areas and structures responsible for sensory perception. Marijuana interferes with the receiving of sensory messages (for example, touch, sight, hearing, taste, and smell) in the cerebral cortex. Various parts of the body send nerve signals to the thalamus, which then routes these messages to the appropriate areas of the cerebral cortex. An area of the sensory cortex, called the somatosensory cortex, receives messages that it interprets as body sensations such as touch and temperature. The somatosensory cortex lies in the parietal lobe of each hemisphere along the central fissure, which separates the frontal and parietal lobes. Each part of the somatosensory cortex receives and interprets impulses from a specific part of the body. Other specialized areas of the cerebrum receive the sensory impulses related to seeing, hearing, taste, and smell. Impulses from the eyes travel along the optic nerve and then are relayed to the visual cortex in the occipital lobes. Portions of the temporal lobes receive auditory messages from the ears. The area for taste lies buried in the lateral fissure, which separates the frontal and temporal lobes. The center for smell is on the underside of the frontal lobes. Marijuana activates cannabinoid receptors in these various areas of the cerebrum and results in the brain misinterpreting the nerve impulses from the different sense organs.

For many years, it was known that THC acted on cannabinoid receptors in the brain. It was

hypothesized that since the normal brain produces these receptors, there must also be a substance produced by the brain itself that acts on these receptors. Despite years of effort, however, the brain's THC-like substance eluded scientists, and whether or not such a substance existed remained a mystery. Finally, in 1992, scientists discovered a substance produced by the brain that activates the THC receptors and has many of the same physiological effects as THC. The scientists named the substance anandamide, from a Sanskrit word meaning bliss. The discovery of anandamide opened whole new avenues of research. For instance, since the brain produces both anandamide and the cannabinoid receptors to which it binds, it was thought that anandamide must play a role in the normal functioning of the brain. Not only are scientists studying anandamide, but more recently additional cannabinoid molecules and receptors have been discovered. One of these, 2-arachidonoglycerol, is a substance that is similar to anandamide, and has a role in controlling pain. Scientists are now actively investigating the function of anandamide and 2-arachidonoglycerol in the brain. The research will not only help in gaining a greater understanding of how marijuana acts in the brain and why it is abused, but it will also provide new clues about how the healthy brain works.



# Marijuana



The discovery of anandamide may also lead to a greater understanding of certain health problems and ultimately to more effective treatments. When made synthetically and given orally, THC can be used to treat nausea associated with chemotherapy and stimulate appetite in AIDS wasting syndrome. Now that the brain's own THC-like substance has been identified, researchers may soon be able to uncover the mechanisms underlying the therapeutic effects of THC. This could then lead to the development of more effective and safer treatments for a variety of conditions.

Recent research in animals has also suggested that long-term use of marijuana (THC) produces some changes in the limbic system that are similar to those that occur after long-term use of other major drugs of abuse such as cocaine, heroin, and alcohol. These changes are most evident during withdrawal from THC. During withdrawal, there are increases in both the levels of a brain chemical involved in stress and certain emotions and the activity of neurons in the amygdala. These same kinds of changes also occur during withdrawal from other drugs of abuse, suggesting that there may be a common factor in the development of drug addiction.

The following activities, when used along with the magazine on marijuana, will help explain to students how these substances change the brain and the body.

# Marijuana



## OBJECTIVES

- ★ **The student will understand the effects of marijuana on brain structures which control the five senses, emotions, memory, and judgment.**
- ★ **The student will use knowledge of brain-behavior relationships to determine the possible effects of marijuana on the ability to perform certain tasks and occupations.**

## OBJECTIVE

- ★ **The student will understand how marijuana interferes with information transfer and short-term memory.**

## OBJECTIVE

- ★ **The student will learn more about the important role of the cerebellum.**

## MARIJUANA ACTIVITY ONE

Review the way in which marijuana use affects brain regions and structures that control the five senses, heart rate, emotions, memory, and judgment. Students then randomly select (for example, draw from a hat) an occupation and are asked to act-out, in front of the class, how marijuana use might specifically affect the performance of a person in that occupation. Examples of occupations can include: an airline pilot, a professional basketball player, a doctor, a defense attorney, a truck driver, a construction worker, a waiter/waitress, a politician, etc. Students will identify the brain regions and structures affected by marijuana use, and describe the link between these structures and behavior.

## MARIJUANA ACTIVITY TWO

Read a list of 20 words aloud to the class and then ask students to write down as many as they can remember. Then have several students stand, in pairs, at various points in the room and carry on loud conversations while you read a list of 20 new words to the remainder of the class. Ask students to again write down as many words as they can remember. Compare performance between the two trials. Mention to the students that, like the disruptive pairs of students, marijuana interferes with normal information transfer and memory. Students will identify the areas of the brain and structures responsible for these functions and will be reminded that marijuana alters neurotransmission in these areas. Students can also search the Internet and other sources to research the effects of marijuana on information transfer and memory and then prepare a brief report summarizing their findings.

## MARIJUANA ACTIVITY THREE

Explain that the cerebellum is involved in balance, coordination, and a variety of other regulatory functions. Marijuana affects the cerebellum, resulting in impairments in motor behavior. Students will search the Internet and other sources for more information about the role and function of the cerebellum and will make a list of ways in which damage to the cerebellum would affect their day-to-day behavior.



# Opiates



## MECHANISM OF ACTION

### BACKGROUND

**Opiates are powerful drugs derived from the poppy plant that have been used for centuries to relieve pain. They include opium, heroin, morphine, and codeine. Even centuries after their discovery, opiates are still the most effective pain relievers available to physicians for treating pain. Although heroin has no medicinal use, other opiates, such as morphine and codeine, are used in the treatment of pain related to illnesses (for example, cancer) and medical and dental procedures. When used as directed by a physician, opiates are safe and generally do not produce addiction. But opiates also possess very strong reinforcing properties and can quickly trigger addiction when used improperly.**

Opiates elicit their powerful effects by activating opiate receptors that are widely distributed throughout the brain and body. Once an opiate reaches the brain, it quickly activates the opiate receptors that are found in many brain regions and produces an effect that correlates with the area of the brain involved. Two important effects produced by opiates, such as morphine, are pleasure (or reward) and pain relief. The brain itself also produces substances known as endorphins that activate the opiate receptors. Research indicates that endorphins are involved in many things, including respiration, nausea, vomiting, pain modulation, and hormonal regulation.

When opiates are prescribed by a physician for the treatment of pain and are taken in the prescribed dosage, they are safe and there is little chance of addiction. However, when opiates are abused and/or taken in excessive doses, addiction can result. Findings from animal research indicate that, like cocaine and other abused drugs, opiates can also activate the brain's reward system. When a person injects, sniffs, or orally ingests heroin (or morphine), the drug travels quickly to the brain through the bloodstream. Once in the brain, the heroin is rapidly converted to morphine, which then activates opiate receptors located throughout the brain, including within the reward system. (Note: Because of its chemical structure, heroin penetrates the brain more quickly than other opiates, which is probably why many addicts prefer heroin.) Within the reward system, the morphine activates opiate receptors in the VTA, nucleus accumbens, and cerebral cortex (refer to the Introduction for information on the reward system). Research suggests that stimulation of opiate receptors by morphine results in feelings of reward and activates the pleasure circuit by causing greater amounts of dopamine to be released within the nucleus accumbens. This causes an intense euphoria, or rush, that lasts only briefly and is followed by a few hours of a relaxed, contented state. This excessive release of dopamine and stimulation of the reward system can lead to addiction.

# Opiates

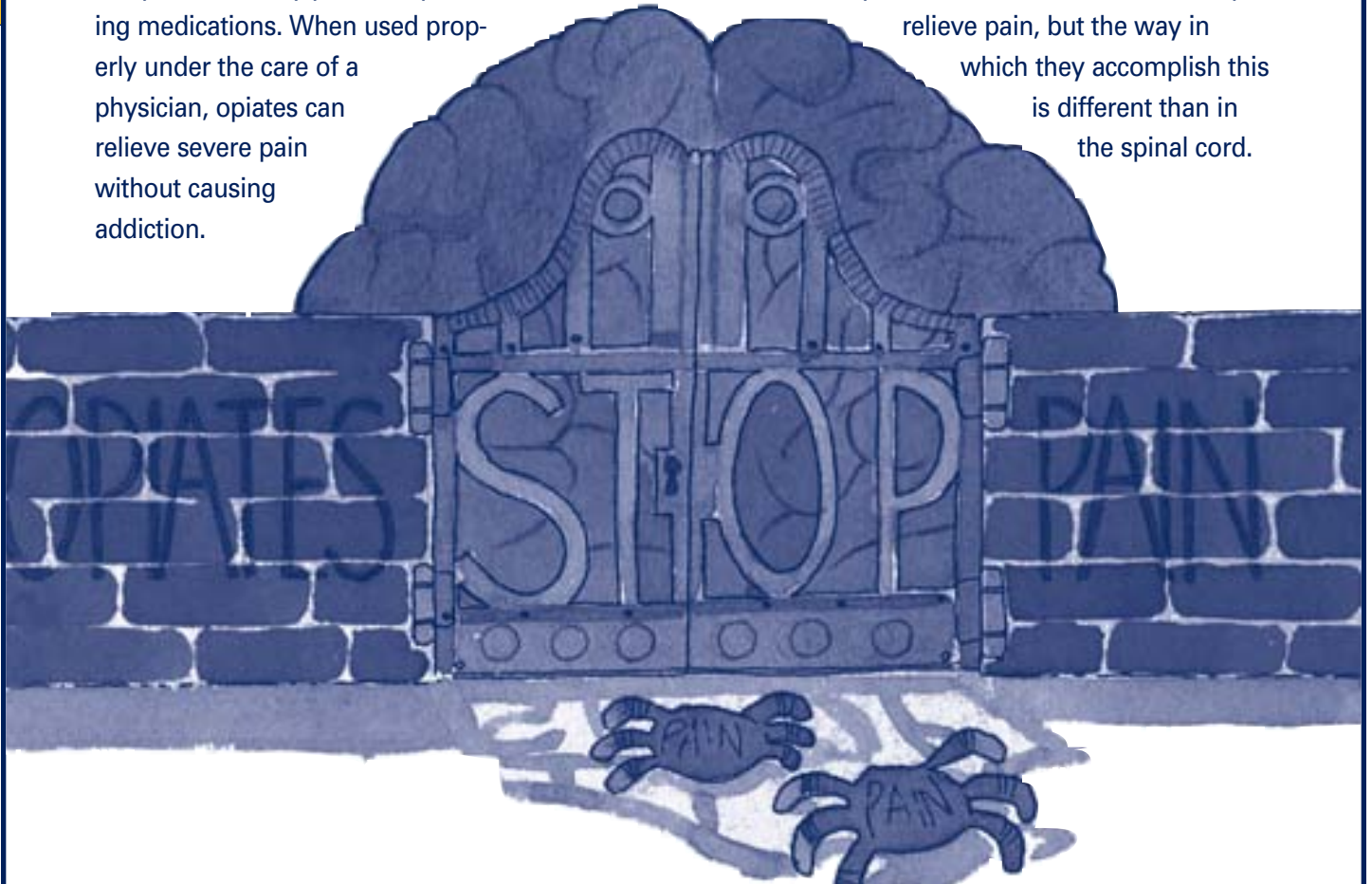
Opiates also act directly on the respiratory center in the brainstem, where they cause a slowdown in activity. This results in a decrease in breathing rate. Excessive amounts of an opiate, like heroin, can cause the respiratory centers to shut down breathing altogether. When someone overdoses on heroin, it is the action of heroin in the brainstem respiratory centers that can cause the person to stop breathing and die.

As mentioned earlier, the brain itself produces endorphins that have an important role in the relief or modulation of pain. Sometimes, though, particularly when pain is severe, the brain does not produce enough endorphins to provide pain relief. Fortunately, opiates, such as morphine are very powerful pain relieving medications. When used properly under the care of a physician, opiates can relieve severe pain without causing addiction.

Feelings of pain are produced when specialized nerves are activated by trauma to some part of the body, either through injury or illness. These specialized nerves, which are located throughout the body, carry the pain message to the spinal cord. After reaching the spinal cord, the message is relayed to other neurons, some of which carry it to the brain. Opiates help to relieve pain by acting in both the spinal cord and brain. At the level of the spinal cord, opiates interfere with the transmission of the pain messages between neurons and therefore prevent them from reaching the brain. This blockade of pain messages protects a person from experiencing too much pain. This is known as analgesia.

Opiates also act in the brain to help relieve pain, but the way in which they accomplish this is different than in the spinal cord.

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# Opiates

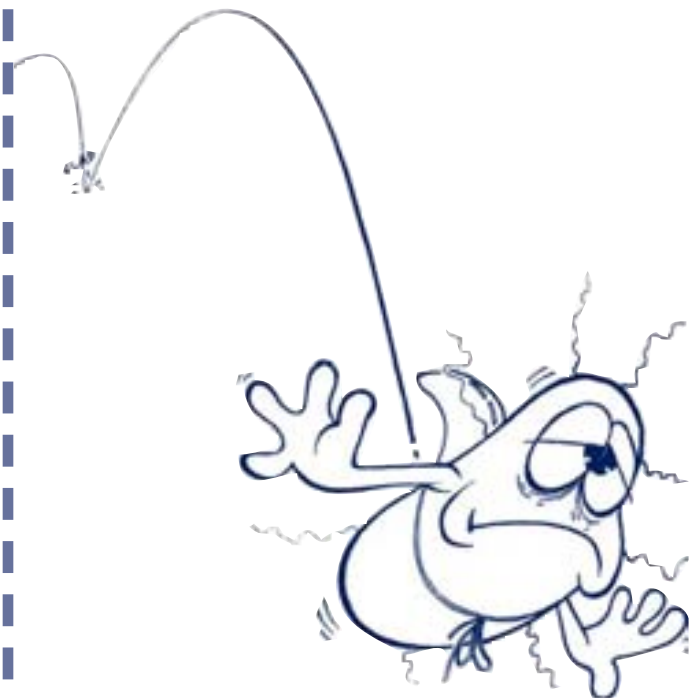
There are several areas in the brain that are involved in interpreting pain messages and in subjective responses to pain. These brain regions are what allow a person to know he or she is experiencing pain and that it is unpleasant. Opiates also act in these brain regions, but they don't block the pain messages themselves. Rather, they change the subjective experience of the pain. This is why a person receiving morphine for pain may say that they still feel the pain but that it doesn't bother them anymore.

Although endorphins are not always adequate to relieve pain, they are very important for survival. If an animal or person is injured and needs to escape a harmful situation, it would be difficult to do so while experiencing severe pain. However, endorphins that are released immediately following an injury can provide enough pain relief to allow escape from a harmful situation. Later, when it is safe, the endorphin levels decrease and intense pain may be felt. This also is important for survival. If the endorphins continued to blunt the pain, it would be easy to ignore an injury and then not seek medical care.

There are several types of opiate receptors, including the delta, mu, and kappa receptors. Each of these three receptors is involved in controlling different brain functions. For example, opiates and endorphins are able to block pain signals by binding to the mu receptor site.

The powerful technology of cloning has enabled scientists to copy the genes that make each of these receptors. This in turn is allowing researchers to conduct laboratory studies to better understand how opiates act in the brain and, more specifically, how opiates interact with each opiate receptor to produce their effects. This information may eventually lead to more effective treatments for pain and opiate addiction.

The following activities, when used along with the magazine on opiates, will help explain to students how these substances change the brain and the body.



# Opiates



## OBJECTIVE

- ★ **The student will learn the way in which opiates alter the function of nerve cells.**

## OPIATES ACTIVITY ONE

Remind students that long-term abuse of opiates, such as heroin, changes the way nerve cells in the brain work. These cells become so used to having the heroin present that they need it to work normally. This, in turn, leads to addiction. If opiates are taken away from dependent nerve cells, these cells become overactive. Eventually, they will work normally again, but in the meantime, they create a range of symptoms known as withdrawal. Have students create visual representations of normal nerve cells, dependent nerve cells, overactive nerve cells, and an opiate. Then have the students use these representations to develop, in comic art format, the process by which opiates change the normal functioning of neurons.

## OBJECTIVE

- ★ **The student will learn how opiates produce an analgesic effect.**

## OPIATES ACTIVITY TWO

Note that opiates are powerful painkillers and are used medically for treatment of pain. When used properly for medical purposes, opiates do not produce an intense feeling of pleasure, and patients have little chance of becoming addicted. Have students search the Internet and other sources for information about pain, pain control, and the way opiates produce their analgesic effect and then prepare a brief summary report.

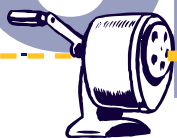
## OBJECTIVE

- ★ **The student will become more familiar with neuroscience concepts and terminology associated with the effects of opiates on the brain.**

## OPIATES ACTIVITY THREE

Students will solve a crossword puzzle which requires knowledge of the ways in which opiates affect brain anatomy and physiology. The puzzle and solution is included in the guide.

# Opiates



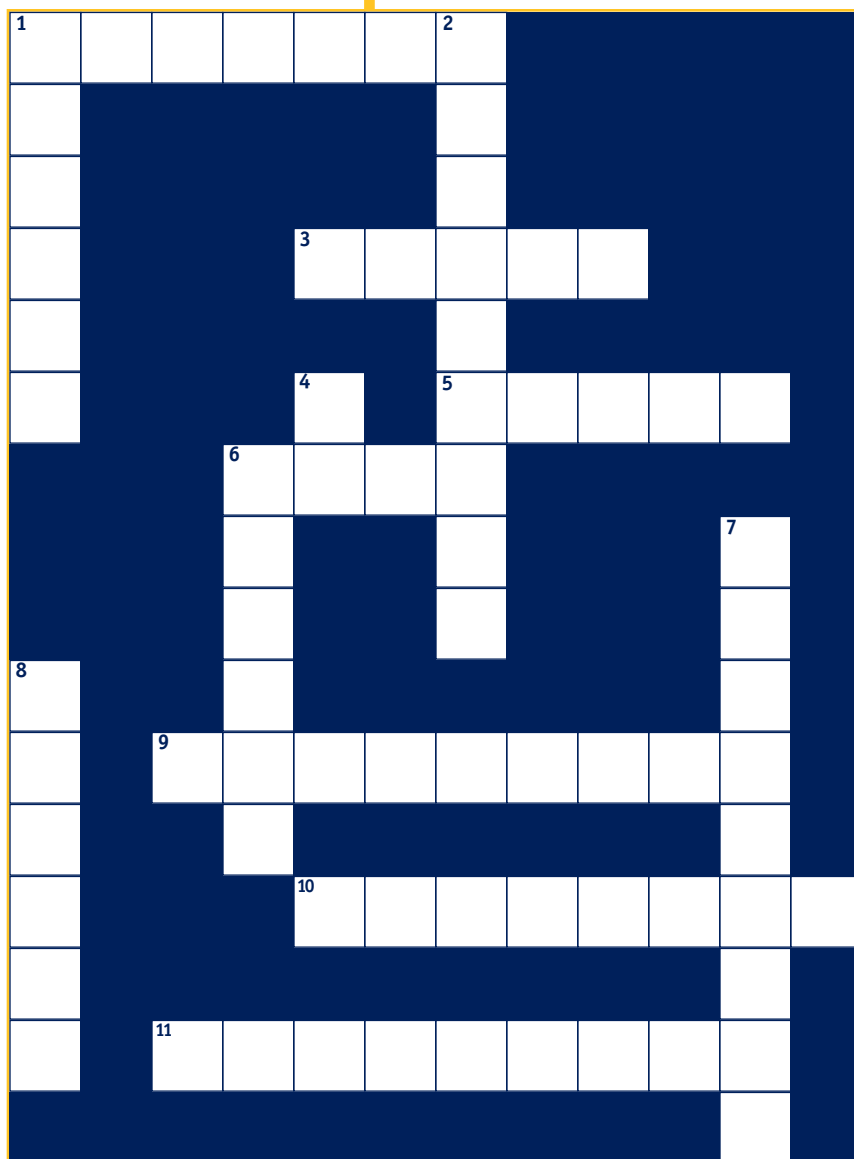
## CROSSWORD PUZZLE

### ACROSS

- 1 Space between neurons
- 3 Copy genetic material to produce an identical cell
- 5 Opiates come from this plant
- 6 Feeling of euphoria
- 9 Controls breathing and heart rate
- 10 Pleasure neurotransmitter
- 11 Pain relief

### DOWN

- 1 Opiates act on the \_\_\_\_\_ cord and brain
- 2 Pain reliever produced by brain
- 4 An opiate receptor
- 6 Another name for pleasure
- 7 Ventral \_\_\_\_\_ area
- 8 Powerful opiate



[illegible]

# Inhalants



## MECHANISM OF ACTION

### BACKGROUND

**Most inhalants are common household products that give off mind-altering chemical fumes when sniffed. These common products include paint thinner, fingernail polish remover, glues, gasoline, cigarette lighter fluid, and nitrous oxide. They also include fluorinated hydrocarbons found in aerosols, such as whipped cream, hair and paint sprays, and computer cleaners. The chemical structure of the various types of inhalants is diverse, making it difficult to generalize about the effects of inhalants. It is known, however, that the vaporous fumes can change brain chemistry and may be permanently damaging to the brain and central nervous system.**

**Inhalant users are also at risk for Sudden Sniffing Death (SSD), which can occur when the inhaled fumes take the place of oxygen in the lungs and central nervous system. This basically causes the inhalant user to suffocate. Inhalants can also lead to death by disrupting the normal heart rhythm, which can lead to cardiac arrest. Use of inhalants can cause hepatitis, liver failure, and muscle weakness. Certain inhalants can also cause the body to produce fewer of all types of blood cells, which may result in life-threatening aplastic anemia.**

**Inhalants also alter the functioning of the nervous system. Some of these effects are transient and disappear after use is discontinued. But inhalant use can also lead to serious neurological problems, some of which are irreversible. For example, frequent long-term use of certain inhalants can cause a permanent change or malfunction of nerves in the back and legs, called polyneuropathy. Inhalants can also act directly in the brain to cause a variety of neurological problems. For instance, inhalants can cause abnormalities in brain areas that are involved in movement (for example, the cerebellum) and higher cognitive function (for example, the cerebral cortex).**

Inhalants enter the bloodstream quickly and are then distributed throughout the brain and body. They have direct effects on both the central nervous system (brain and spinal cord) and the peripheral nervous system (nerves throughout the body).

Using brain imaging techniques, such as magnetic resonance imaging (MRI), researchers have discovered that there are marked structural changes in the brains of chronic inhalant abusers. These changes include a reduction in size in certain brain areas, including the cerebral cortex, cerebellum, and brainstem. These changes may account for some of the neurological and behavioral symptoms that long-term inhalant abusers exhibit (for example, cognitive and motor difficulties). Some of these changes may be due to the effect inhalants have on myelin, the fatty tissue which insulates and protects axons and helps speed up nerve conduction. When inhalants enter the brain and body, they are particularly attracted to fatty tissues. Because myelin is a fat, it quickly absorbs inhalants, which can then damage or even destroy the myelin. The deterioration of myelin interferes with the rapid flow of messages from one nerve to another.

Inhalants can also have a profound effect on nerves that are located throughout the body. The polyneuropathy caused by some inhalants, as well as other neurological problems, may be due in part to the effect of the inhalants on the myelin sheath that covers axons throughout the body. In some cases, not only is the myelin destroyed, but the axons themselves degenerate.

The following activities, when used along with the magazine on inhalants, will help explain to students how these substances change the brain and the body.

# Inhalants



## OBJECTIVE

- ★ **The student will learn the effects of inhalant use on brain-behavior relationships.**

## INHALANTS ACTIVITY ONE

Introduce this activity by reminding students that inhalants can slow or stop nerve cell activity in some parts of the brain; for example, the frontal lobes (complex problem solving), cerebellum (movement and coordination), and hippocampus (memory). Students will break into small groups and contribute in a round-robin fashion to a story about a fictional student who uses inhalants. The students should be encouraged to include problems (symptoms) in the description that would be associated with inhalant use, as well as other symptoms that would not. These stories can then be shared (either in oral or written form) with the rest of the class, who will be required to identify the inhalant-related behavioral components and then describe the brain areas that are involved in these behaviors. Students will then search the Internet and other sources to obtain information about the way in which activity in the frontal lobes, cerebellum, and hippocampus influences behavior, and prepare a report summarizing their findings.

## OBJECTIVE

- ★ **The student will understand the effect of inhalants on brain structures, physiology, and behavior.**

## INHALANTS ACTIVITY TWO

Review the regions of the brain and structures affected by inhaling solvents, gases, and nitrites. Then divide the class into groups of 4-6, and have each group write a rap music video about the effects of inhalants on brain areas and structures, as well as brain-behavior relationships. When the songs are finished, have each group perform their music video.

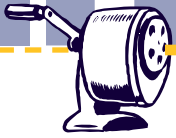
## OBJECTIVE

- ★ **The student will become more familiar with the neuroscience concepts and terminology associated with the effects of inhalants on the brain and body.**

## INHALANTS ACTIVITY THREE

The students will complete the Inhalants Word Search, and the teacher will then review the words and have the students discuss how the terms relate to inhalant use. A copy of the Word Search and the Word Search Solution is included in the guide.

# Inhalants



## WORD SEARCH

A	A	L	A	D	G	Y	M	A	N	Y
Z	U	X	I	I	M	P	A	M	A	V
S	D	B	F	N	Z	J	L	R	C	P
H	J	P	W	H	M	G	R	O	E	S
B	N	O	X	A	I	S	O	P	R	B
A	F	L	J	L	K	O	W	A	E	W
T	E	Y	K	A	I	B	Y	V	B	E
D	V	N	K	N	D	V	B	S	E	Q
C	S	E	G	T	N	N	E	U	L	G
B	G	U	K	C	E	L	L	R	L	S
T	X	R	F	L	Y	P	L	M	U	X
I	E	O	R	F	U	M	E	S	M	F
D	T	P	F	W	O	K	R	Y	O	N
J	R	A	X	F	A	C	E	C	P	R
C	O	T	F	Y	I	L	A	Z	U	Y
T	C	H	L	X	I	N	B	T	D	I
E	H	Y	H	N	X	V	S	T	E	C
U	E	O	R	L	N	Q	O	H	A	G

Amygdala

Fumes

Myelin

Axon

Glue

Polyneuropathy

Cell

Inhalant

Sniff

Cerebellum

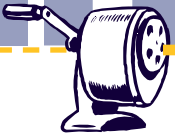
Kidney

Vapor

Cortex

Liver





## WORD SEARCH

A	A	L	A	D	G	Y	M	A	N	Y
Z	U	X	I	I	M	P	A	M	A	V
S	D	B	F	N	Z	J	L	R	C	P
H	J	P	W	H	M	G	R	O	E	S
B	N	O	X	A	I	S	O	P	R	B
A	F	L	J	L	K	O	W	A	E	W
T	E	Y	K	A	I	B	Y	V	B	E
D	V	N	K	N	D	V	B	S	E	Q
C	S	E	G	T	N	N	E	U	L	G
B	G	U	K	C	E	L	L	R	L	S
T	X	R	F	L	Y	P	L	M	U	X
I	E	O	R	F	U	M	E	S	M	F
D	T	P	F	W	O	K	R	Y	O	N
J	R	A	X	F	A	C	E	C	P	R
C	O	T	F	Y	I	L	A	Z	U	Y
T	C	H	L	X	I	N	B	T	D	I
E	H	Y	H	N	X	V	S	T	E	C
U	E	O	R	L	N	Q	O	H	A	G

Amygdala

Fumes

Myelin

Axon

Glue

Polyneuropathy

Cell

Inhalant

Sniff

Cerebellum

Kidney

Vapor

Cortex

Liver

# Hallucinogens



## BACKGROUND

Hallucinogens are drugs which cause altered states of perception and feeling and which can produce flashbacks. They include natural substances, such as mescaline and psilocybin that come from plants (cactus and mushrooms), and chemically manufactured ones, such as LSD and MDMA (ecstasy). LSD is manufactured from lysergic acid, which is found in ergot, a fungus that grows on rye and other grains. MDMA is a synthetic mind-altering drug with both stimulant and hallucinogenic properties.

Although not a true hallucinogen in the pharmacological sense, PCP causes many of the same effects as hallucinogens and so is often included with this group of drugs. Hallucinogens have powerful mind-altering effects. They can change how the brain perceives time, everyday reality, and the surrounding environment. They affect regions and structures in the brain that are responsible for coordination, thought processes, hearing, and sight. They can cause people who use them to hear voices, see images, and feel sensations that do not exist. Researchers are not certain that brain chemistry permanently changes from hallucinogen use, but some people who use them appear to develop chronic mental disorders. PCP and MDMA can be addictive; whereas LSD, psilocybin, and mescaline are not.

Research has provided many clues about how hallucinogens act in the brain to cause their powerful effects. However, because there are different types of hallucinogens and their effects are so widespread, there is still much that is unknown. The following paragraphs describe some of what is known about this diverse group of drugs.

## MECHANISM OF ACTION

LSD binds to and activates a specific receptor for the neurotransmitter serotonin. Normally, serotonin binds to and activates its receptors and then is taken back up into the neuron that released it. In contrast, LSD binds very tightly to the serotonin receptor, causing a greater than normal activation of the receptor. Because serotonin has a role in many of the brain's functions, activation of its receptors by LSD produces widespread effects, including rapid emotional swings, and altered perceptions, and if taken in a large enough dose, delusions and visual hallucinations.

MDMA, which is similar in structure to methamphetamine and mescaline, causes serotonin to be released from neurons in greater amounts than normal. Once released, this serotonin can excessively activate serotonin receptors. Scientists have also shown that MDMA causes excess dopamine to be released from dopamine-containing neurons. Particularly alarming is research in animals that has demonstrated that MDMA can damage serotonin-containing neurons. MDMA can cause confusion, depression, sleep problems, drug craving, and severe anxiety.

PCP, which is not a true hallucinogen, can affect many neurotransmitter systems. It interferes with the functioning of the neurotransmitter glutamate, which is found in neurons throughout the brain. Like many other drugs, it also causes dopamine to be released from neurons into the synapse. At low to moderate doses, PCP causes altered perception of body image, but rarely produces visual hallucinations. PCP can also cause effects that mimic the primary symptoms of schizophrenia, such as delusions and mental turmoil. People who use PCP for long periods of time have memory loss and speech difficulties.

The following activities, when used along with the magazine on hallucinogens, will help explain to students how these substances change the brain and the body.

# Hallucinogens



## OBJECTIVE

- ★ **The student will learn how hallucinogens cause visual misperception and hallucinations.**

## HALLUCINOGENS ACTIVITY ONE

Have students draw a bull's-eye onto a sheet of unruled white paper. Make a small "X" at the center of another sheet of paper. Now, have the students stare at the bull's-eye for about 20 seconds and then quickly shift their focus to the "X." Students will find that an after-image of the bull's-eye will appear. Explain that after-images are a class of optical illusions, which have some similarity to hallucinations. Have students search the Internet and other sources for information about drug-induced hallucinations and prepare a report summarizing their findings.

## OBJECTIVE

- ★ **The student will learn that hallucinogens cause other sensory misperceptions.**

## HALLUCINOGENS ACTIVITY TWO

Fill one bowl with warm water, another with cold water, and a third with water at room temperature. First, have the students place the fingers of one hand in the warm water. Wait 60 seconds. Then have them place their fingers in the room temperature water and describe the temperature of the water (feels cool). Then have the students place their fingers of the other hand in the cold water. Wait 60 seconds. Then have them place their fingers in the room temperature water and describe the temperature of the water (feels hot). Remind students that hallucinogens can affect the way we perceive reality.

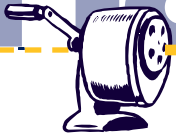
## OBJECTIVE

- ★ **The student will learn vocabulary and facts associated with hallucinogens.**

## HALLUCINOGENS ACTIVITY THREE

Instruct the students to complete the Hallucinogens Word Puzzle. The puzzle and solution to the puzzle are included in the guide.

# Hallucinogens



## WORD PUZZLE

Answer each question below, then correctly arrange the boxed letters to solve the riddle at the bottom of the page.

1 \_\_\_\_\_  \_\_\_\_\_  \_\_\_\_\_  
LSD binds tightly to and activates the receptor for what neurotransmitter?

2 \_\_\_\_\_  \_\_\_\_\_  
What drug comes from a cactus plant?

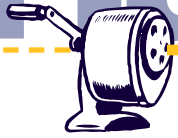
3 \_\_\_\_\_  \_\_\_\_\_  
What is another name for MDMA?

4  \_\_\_\_\_  \_\_\_\_\_  
Neurotransmitters attach to what molecules in the cell membrane?

5 \_\_\_\_\_  \_\_\_\_\_  
What is another name for LSD?

6  \_\_\_\_\_  
Changes in what brain structure affect breathing and heart rate?

**What might result if you use either  
hallucinogens, or a lousy travel agent?**



## WORD PUZZLE

SOLUTION

Answer each question below, then correctly arrange the boxed letters to solve the riddle at the bottom of the page.

1 S E R O T O N I N  
LSD binds tightly to and activates the receptor for what neurotransmitter?

2 M E S C A L I N E  
What drug comes from a cactus plant?

3 E C S T A C Y  
What is another name for MDMA?

4 R E C E P T O R S  
Neurotransmitters attach to what molecules in the cell membrane?

5 A C I D  
What is another name for LSD?

6 B R A I N S T E M  
Changes in what brain structure affect breathing and heart rate?

A B A D T R I P

**What might result if you use either hallucinogens, or a lousy travel agent?**

# Steroids



## MECHANISM OF ACTION

## BACKGROUND

**Anabolic steroids are chemicals that are similar to the male sex hormone testosterone and are used by an increasing number of young people to enhance their muscle size. While anabolic steroids are quite successful at building muscle, they can damage many body organs, including the liver, kidneys, and heart. They may also trigger dependency in users, particularly when taken in the large doses that have been known to be used by many bodybuilders and athletes.**

Anabolic steroids are taken either orally in pill form or by injection. After steroids enter the bloodstream, they are distributed to organs (including muscle) throughout the body. After reaching these organs, the steroids surround individual cells in the organ and then pass through the cell membranes to enter the cytoplasm of the cells. Once in the cytoplasm, the steroids bind to specific receptors and then enter the nucleus of the cells. The steroid-receptor complex is then able to alter the functioning of the genetic material and stimulate the production of new proteins. It is these proteins that carry out the effects of the steroids. The types of proteins and the effects vary depending on the specific organ involved. Steroids are able to alter the functioning of many organs, including the liver, kidneys, heart, and brain. They can also have a profound effect on reproductive organs and hormones.

Many of the effects of steroids are brought about through their actions in the brain. Once steroids enter the brain, they are distributed to many regions, including the hypothalamus and limbic system. When a person takes steroids, the functioning of neurons in both of these areas is altered, resulting in a change in the types of messages that are transmitted by the neurons. Since the hypothalamus has a major role in maintaining normal hormone levels, disrupting its normal functioning also disrupts the body's hormones. This can result in many problems, including a reduction in normal testosterone production in males and loss of the monthly period in females.

Similarly, steroids can also disrupt the functioning of neurons in the limbic system. The limbic system is involved in many things, including learning, memory, and regulation of moods. Studies in animals have shown that steroids can impair learning and memory. They can also promote overly-aggressive behavior and mood swings. People who take anabolic steroids can exhibit violent behavior, impairment of judgment, and even psychotic symptoms.

Other effects of taking anabolic steroids include changes in male and female sexual characteristics, stunted growth, and an increase in the amount of harmful cholesterol in the body. Anabolic steroids can also influence the growth of facial and chest hair and cause a deepening of the voice.

The following activities, when used along with the magazine on anabolic steroids, will help explain to students how these substances change the brain and the body.

# Steroids



## OBJECTIVE

- ★ **The student will understand that steroids have a direct effect on the limbic system, which has a large role in the expression of emotions.**

## STERIODS ACTIVITY ONE

Ask students to imagine a time when they experienced, very suddenly, either intense rage or aggressiveness. Those who would like to can share some of these experiences with the class. Reinforce that the limbic system was likely involved in these reactions and that steroid use directly increases the likelihood of such episodes. Mention that neuroscientists have long known about the important role the limbic system plays in emotions and have conducted animal research in which stimulating certain limbic system structures produces a rage reaction in a normally docile animal, while stimulating other structures makes a normally vicious animal calm and relaxed. Have students conduct research using the Internet and other sources to learn more about the role of the limbic system.

## OBJECTIVE

- ★ **The student will learn more about the functions of key neurotransmitters including serotonin, glutamate, dopamine, and acetylcholine.**

## STERIODS ACTIVITY TWO

Indicate that steroids affect the function of several neurotransmitters, adding that each neurotransmitter communicates different types of messages. For example, glutamate communicates excitement, acetylcholine tells the heart to beat slower and commands memory circuits to store or remember thoughts, serotonin controls emotions and mood, and dopamine affects feelings of pleasure. Students will select a neurotransmitter and search the Internet and other sources for additional information. They will prepare a brief report summarizing their findings and create a comic art rendition of their neurotransmitter.

## OBJECTIVE

- ★ **The student will learn about the performance enhancing effects of steroids, and the medical risk factors.**

## STERIODS ACTIVITY THREE

Remind students that despite their dangerous side effects, anabolic steroids are used by some high school, college, and professional athletes to give them the “edge” they feel they need to outperform the competition. Discuss with the students the short- and long-term dangers associated with the use of steroids for enhancing performance. A useful example for this discussion might be Lyle Alzado, a former professional football star who died from cancer attributed to steroid use.



# Stimulants



## MECHANISM OF ACTION

### BACKGROUND

**Stimulant drugs such as cocaine, “crack,” amphetamines, and caffeine are substances that speed up activity in the brain and spinal cord. This, in turn, can cause the heart to beat faster and blood pressure and metabolism to increase. Stimulants often influence a person to be more talkative and anxious and to experience feelings of exhilaration.**

**Use of cocaine and other stimulants can cause someone’s heart to beat abnormally fast and at an unsteady rate. Use of these drugs also narrows blood vessels, reducing the flow of blood and oxygen to the heart, which results in “starving” the heart muscle. Even professional athletes whose bodies are well-conditioned have succumbed to cocaine’s ability to cause heart failure. Researchers currently have no way to detect who may be more susceptible to these effects.**

Cocaine acts on the pleasure circuit to prevent reabsorption of the neurotransmitter dopamine after its release from nerve cells. Normally, neurons that are part of the pleasure circuit release dopamine, which then crosses the synapse to stimulate another neuron in the pleasure circuit. Once this has been accomplished, the dopamine is picked up by a transporter molecule and carried back into the original neuron. However, because cocaine binds to the dopamine transporter molecule, it prevents the reabsorption of dopamine. This causes a buildup of dopamine in the synapse, which results in strong feelings of pleasure and even euphoria. The excess dopamine that accumulates in the synapse causes the neurons that have dopamine receptors to decrease the number of receptors they make. This is called down regulation. When cocaine is no longer taken and dopamine levels return to their normal (i.e., lower) concentration, the smaller number of dopamine receptors that are available for the neurotransmitter to bind to is insufficient to fully activate nerve cells. During “craving,” the addict experiences a very strong need for the drug to get the level of dopamine back up. Cocaine also binds to the transporters for other neurotransmitters, including serotonin and norepinephrine, and blocks their re-uptake. Scientists are still unsure about the effects of cocaine’s interaction with these other neurotransmitters.

Cocaine has also been found to specifically affect the pre-frontal cortex and amygdala, which are involved in aspects of memory and learning. The amygdala has been linked to emotional aspects of memory. Researchers believe that a neural network involving these brain regions reacts to environmental cues and activates memories, and this triggers biochemical changes that result in cocaine craving.

# Stimulants

Amphetamines, such as methamphetamine, also act on the pleasure circuit by altering the levels of certain neurotransmitters present in the synapse, but the mechanism is different from that of cocaine. Methamphetamine is chemically similar to dopamine. This similarity allows methamphetamine to fool the dopamine transporter into carrying methamphetamine into the nerve terminal. Methamphetamine can also directly cross nerve cell membranes. Once inside nerve terminals, methamphetamine enters dopamine vesicles and causes the release of these neurotransmitters. The excess dopamine is then carried by transporter molecules out of the neuron and into the synapse. Once in the synapse, the high concentration of dopamine causes feelings of pleasure and euphoria.

Methamphetamine also differs from cocaine in that it can damage neurons that contain dopamine and even kill neurons that contain other neurotransmitters. This cell damage can occur in the frontal cortex, amygdala and the striatum, a brain region that is involved in movement. This may account for the dramatic

decrease in dopamine levels seen with brain imaging techniques in both humans and animals. These decreases in dopamine are seen even after short-term exposure to methamphetamine and they persist for many years, even after methamphetamine use has been terminated.

For more information on how methamphetamine acts in the brain, see the last chapter which is devoted entirely to methamphetamine.

The following activities, when used along with the magazine on stimulants, will help explain to students how these substances change the brain and the body.



# Stimulants



## OBJECTIVE

- ★ The student will learn that cocaine affects neurotransmission in the mesolimbic dopamine system, sometimes referred to as the pleasure center.

## COCAINE ACTIVITY ONE

Remind students that cocaine activates the brain's pleasure center, which involves the brainstem, limbic system, and frontal cortex. Students will then produce colorful diagrams of the system, labeling important parts, and provide a brief written description of the different structures.

## OBJECTIVES

- ★ The student will learn the way in which dopamine is related to the sensation of pleasure.
- ★ The student will learn how stimulants interfere with dopamine re-uptake.

## COCAINE ACTIVITY TWO

Describe how cocaine ultimately reduces pleasure by interfering with dopamine re-uptake. Students will be assigned to groups and will first script and then act out this process. They will then perform their skits with students assuming roles such as neurons, cocaine, transporters, receptors, dopamine, pleasure, and addiction.

## OBJECTIVE

- ★ The student will learn and share interesting and unusual information about the effects of cocaine, amphetamines, and caffeine on the brain and behavior.

## COCAINE ACTIVITY THREE

Divide the students into three groups (cocaine, amphetamines, and caffeine), and assign each group the task of researching their assigned drug in order to develop a "Did You Know" poster for each type of drug. Encourage each group to discover some "surprising" information to include on their poster, and ask that each poster contain a minimum of 10 new and/or unusual facts. Students will use the local public library, the Internet, other multimedia materials, and any other sources to obtain this information. They will then work together to develop the graphics and text. Display the finished posters.





# Nicotine



## MECHANISM OF ACTION

## BACKGROUND

**Tobacco, which comes primarily from the plant *nicotiana tabacum*, has been used for centuries. It can be smoked, chewed, or sniffed. The first description of addiction to tobacco is contained in a report from the New World in which Spanish soldiers said that they could not stop smoking.**

**When nicotine was isolated from tobacco leaves in 1828, scientists began studying its effects in the brain and body.**

**This research eventually showed that, although tobacco contains thousands of chemicals, the main ingredient that acts in the brain and produces addiction is nicotine. More recent research has shown that the addiction produced by nicotine is extremely powerful and is at least as strong as addictions to other drugs such as heroin and cocaine.**

**Some of the effects of nicotine include changes in respiration and blood pressure, constriction of arteries, and increased alertness. Many of these effects are produced through its action on both the central and peripheral nervous systems.**

Nicotine readily enters the body. When tobacco is smoked, nicotine enters the bloodstream through the lungs. When it is sniffed or chewed, nicotine passes through the mucous membranes of the mouth or nose to enter the bloodstream. Nicotine can also enter the bloodstream by passing through the skin. Regardless of how nicotine reaches the bloodstream, once there, it is distributed throughout the body and brain where it activates specific types of receptors known as cholinergic receptors.

Cholinergic receptors are present in many brain structures, as well as in muscles, adrenal glands, the heart, and other body organs. These receptors are normally activated by the neurotransmitter acetylcholine, which is produced in the brain, and by neurons in the peripheral nervous system. Acetylcholine and its receptors are involved in many activities, including respiration, maintenance of heart rate, memory, alertness, and muscle movement.

Because the chemical structure of nicotine is similar to that of acetylcholine, it is also able to activate cholinergic receptors. But unlike acetylcholine, when nicotine enters the brain and activates cholinergic receptors, it can disrupt the normal functioning of the brain.

Regular nicotine use causes changes in both the number of cholinergic receptors and the sensitivity of these receptors to nicotine and acetylcholine. Some of these changes may be responsible for the development of tolerance to nicotine. Tolerance occurs when more drug is needed to achieve the same or similar effects. Once tolerance has developed, a nicotine user must regularly supply the brain with nicotine in order to maintain normal brain functioning. If nicotine levels drop, the nicotine user will begin to feel uncomfortable withdrawal symptoms.

# Nicotine

Recently, research has shown that nicotine also stimulates the release of the neurotransmitter dopamine in the brain's pleasure circuit. Using microdialysis, a technique that allows minute quantities of neurotransmitters to be measured in precise brain areas, researchers have discovered that nicotine causes an increase in the release of dopamine in the nucleus accumbens. This release of dopamine is similar to that seen for other drugs of abuse, such as heroin and cocaine, and is thought to underlie the pleasurable sensations experienced by many smokers.

Other research is providing even more clues as to how nicotine may exert its effects in the brain. Cholinergic receptors are relatively large structures that consist of several components known as subunits. One of these subunits, the  $\beta$  (beta) subunit, has recently been implicated in nicotine addiction. Using highly sophisticated bioengineering technologies, scientists were able to produce a new strain of mice in which the gene that produces the  $\beta$  subunit was missing. Without the gene for the  $\beta$  subunit, these mice, which are known as "knock-

out" mice because a particular gene has been knocked out, were unable to produce any  $\beta$  subunits. What researchers found when they examined these knockout mice was that in contrast to mice who had an intact receptor, mice without the  $\beta$  subunit would not self-administer nicotine. These studies demonstrate that the  $\beta$  subunit plays a critical role in the addictive properties of nicotine. The results also provide scientists with valuable new information about how nicotine acts in the brain, information that may eventually lead to better treatments for nicotine addiction.

However, nicotine may not be the only psychoactive ingredient in tobacco. Using advanced brain imaging technology, it is possible to actually see what tobacco smoking is doing to the brain of an awake and behaving human being. Using one type of brain imaging, positron emission tomography (PET), scientists discovered that cigarette smoking causes a dramatic decrease in the levels of an important enzyme that breaks down dopamine and other neurotransmitters.



# Nicotine

The decrease in this enzyme, known as monoamine-oxidase-A (MAO-A), results in an increase in dopamine levels. Importantly, this particular effect is not caused by nicotine but by some additional, unknown compound in cigarette smoke. Nicotine itself does not alter MAO-A levels; it affects dopamine through other mechanisms. Thus, there may be multiple routes by which smoking alters the neurotransmitter dopamine to ultimately produce feelings of pleasure and reward.

That nicotine is a highly addictive drug can clearly be seen when one considers the vast number of people who continue to use tobacco products despite their well known harmful and even lethal effects. In fact, at least 90% of smokers would like to quit, but each year fewer than 10% who try are actually successful. But, while nicotine may produce addiction to tobacco products, it is the thousands of other chemicals in tobacco that are responsible for its many adverse health effects.

Smoking either cigarettes or cigars can cause respiratory problems, lung cancer, emphysema, heart problems, and peripheral vascular disease. In fact, smoking is the largest preventable cause of premature death and disability. Cigarette smoking kills at least 400,000 people in the United States each year and makes countless others ill, including those who are exposed to secondhand smoke. The use of smokeless tobacco is also associated with serious health problems.

Chewing tobacco can cause cancers of the oral cavity, pharynx, larynx, and esophagus. It also causes damage to gums that may lead to the loss of teeth. Although popular among sports figures, smokeless tobacco can also reduce physical performance.

The following activities, when used along with the magazine on nicotine, will help explain to students how these substances change the brain and the body.





# Nicotine



## OBJECTIVE

- ★ **The student will become more familiar with the neuroscience concepts and terminology associated with the effects of nicotine and tobacco products on the brain and body.**

## OBJECTIVE

- ★ **The student will understand that nicotine is a highly addictive drug and that once someone has become addicted, it is very difficult to stop smoking, even in the face of serious health consequences.**

## OBJECTIVE

- ★ **The student will learn that cigarette smoke contains molecules that are deposited along the entire respiratory tract, including the lungs. These molecules not only turn the lungs and other parts of the respiratory system black, but they also cause cancers and other respiratory illnesses.**

## NICOTINE ACTIVITY ONE

The students will complete the Nicotine Word Find, and the teacher will then review the words and have the students discuss how the terms relate to tobacco use. A copy of the Word Search and Word Search Solution is included in the guide.

## NICOTINE ACTIVITY TWO

The students will call local hospitals to obtain the names of physicians who provide treatment to people trying to stop their use of tobacco products. The students will then compose a letter to one or more of these physicians inviting them to come and speak to the class on the difficulties associated with quitting smoking or the use of other tobacco products. Prior to the visit by the physician, the students will prepare a list of questions that they would like to ask. These questions might include the following: 1) How many people succeed the first or even second time they try to stop smoking? 2) How many people try repeatedly to quit smoking without success? 3) Do people still smoke even when they have a life-threatening illness, such as heart disease or lung cancer?

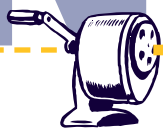
## NICOTINE ACTIVITY THREE

The students will conduct the following experiment:

Materials needed: cigarette, transparent plastic syringe, cotton balls, matches or lighter

Fill the syringe with the cotton balls. Insert the end of the syringe onto the filter of the cigarette. Light the cigarette and pull back the plunger to draw smoke into the barrel of the syringe. Have the students watch the cotton balls turn black as the smoke particles are deposited. Discuss with the students what they have observed. Students might consider what the effects of smoking several cigarettes a day for many years would have on the lungs if only one cigarette can turn a cotton ball black.

# Nicotine



## WORD SEARCH

A	Z	W	S	A	M	E	S	Y	H	P	M	E
R	O	T	P	E	C	E	R	Q	Y	I	N	P
R	E	S	L	O	L	J	G	T	R	I	E	N
B	N	I	A	R	B	U	O	D	L	P	U	M
L	R	Z	W	A	R	T	M	O	O	T	R	K
O	X	Q	A	D	E	I	H	P	R	Z	O	R
O	Q	A	R	W	O	C	C	A	B	O	T	N
D	S	E	D	E	L	D	G	M	R	F	R	O
S	Y	G	H	Y	U	I	J	I	K	I	A	I
T	X	P	T	C	C	L	V	N	J	B	N	T
R	N	E	I	M	A	R	T	E	Y	I	S	C
E	C	Q	W	O	Z	C	D	O	P	M	M	I
A	D	D	R	Y	C	T	A	R	E	N	I	D
M	O	T	K	Z	Q	P	O	N	A	T	T	D
N	E	T	T	E	R	A	G	I	C	W	T	A
G	E	U	N	I	C	O	T	I	N	E	E	L
A	L	S	G	N	I	K	O	M	S	I	R	R

EMPHYSEMA

NEUROTRANSMITTER

CIGAR

DOPAMINE

ADDICTION

REWARD

SMOKING

WITHDRAWAL

CIGARETTE

CANCER

DRUG

ACETYLCHOLINE

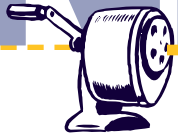
BRAIN

BLOODSTREAM

RECEPTOR

NICOTINE

TOBACCO



# Nicotine

## WORD SEARCH

SOLUTION

A	Z	W	S	A	M	E	S	Y	H	P	M	E
R	O	T	P	E	C	E	R	Q	Y	I	N	P
R	E	S	L	O	L	J	G	T	R	I	E	N
B	N	I	A	R	B	U	O	D	L	P	U	M
L	R	Z	W	A	R	T	M	O	O	T	R	K
O	X	Q	A	D	E	I	H	P	R	Z	O	R
O	Q	A	R	W	O	C	C	A	B	O	T	N
D	S	E	D	E	L	D	G	M	R	F	R	O
S	Y	G	H	Y	U	I	J	I	K	I	A	I
T	X	P	T	C	C	L	V	N	J	B	N	T
R	N	E	I	M	A	R	T	E	Y	I	S	C
E	C	Q	W	O	Z	C	D	O	P	M	M	I
A	D	D	R	Y	C	T	A	R	E	N	I	D
M	O	T	K	Z	Q	P	O	N	A	T	T	D
N	E	T	T	E	R	A	G	I	C	W	T	A
G	E	U	N	I	C	O	T	I	N	E	E	L
A	L	S	G	N	I	K	O	M	S	I	R	R

EMPHYSEMA

NEUROTRANSMITTER

CIGAR

DOPAMINE

ADDICTION

REWARD

SMOKING

WITHDRAWAL

CIGARETTE

CANCER

DRUG

ACETYLCHOLINE

BRAIN

BLOODSTREAM

RECEPTOR

NICOTINE

TOBACCO



# Methamphetamine



## MECHANISM OF ACTION

### BACKGROUND

**Methamphetamine is an addictive drug that belongs to a class of drugs known as stimulants. This class also includes cocaine, caffeine, and other drugs.**

**Methamphetamine is made illegally with relatively inexpensive over-the-counter ingredients. Many of the ingredients that are used to produce methamphetamine, such as drain cleaner, battery acid, and antifreeze, are extremely dangerous. The rapid proliferation of "basement" laboratories for the production of methamphetamine has led to a widespread problem in many communities in the U.S.**

**Methamphetamine has many effects in the brain and body. Short-term effects can include increased wakefulness, increased physical activity, decreased appetite, increased respiration, hyperthermia, irritability, tremors, convulsions, and aggressiveness.**

**Hyperthermia and convulsions can result in death. Single doses of methamphetamine have also been shown to cause damage to nerve terminals in studies with animals. Long-term effects can include addiction, stroke, violent behavior, anxiety, confusion, paranoia, auditory hallucinations, mood disturbances, and delusions. Long-term use can also cause damage to dopamine neurons that persists long after the drug has been discontinued.**

Methamphetamine acts on the pleasure circuit in the brain by altering the levels of certain neurotransmitters present in the synapse. Chemically, methamphetamine is closely related to amphetamine, but its effects on the central nervous system are greater than those of amphetamine.

Methamphetamine is also chemically similar to dopamine and another neurotransmitter, norepinephrine. It produces its effects by causing dopamine and norepinephrine to be released into the synapse in several areas of the brain, including the nucleus accumbens, prefrontal cortex, and the striatum, a brain area involved in movement. Specifically, methamphetamine enters nerve terminals by passing directly through nerve cell membranes. It is also carried into the nerve terminals by transporter molecules that normally carry dopamine or norepinephrine from the synapse back into the nerve terminal. Once in the nerve terminal, methamphetamine enters dopamine and norepinephrine containing vesicles and causes the release of these neurotransmitters. Enzymes in the cell normally chew up excess dopamine and norepinephrine; however, methamphetamine blocks this breakdown. The excess neurotransmitters are then carried by transporter molecules out of the neuron and into the synapse. Once in the synapse, the high concentration of dopamine causes feelings of pleasure and euphoria. The excess norepinephrine may be responsible for the alertness and anti-fatigue effects of methamphetamine.

Methamphetamine can also affect the brain in other ways. For example, it can cause cerebral edema, brain hemorrhage, paranoia, and hallucinations. Some of the effects of methamphetamine on the brain may be long-lasting and even permanent. Recent research in humans has shown that even three years after chronic methamphetamine users have discontinued use of the drug there is still a reduction in their ability to transport dopamine back into neurons. This clearly demonstrates that there is a long-lasting impairment in

# Methamphetamine

dopamine function as a result of drug use. This is highly significant because dopamine has a major role in many brain functions, including experiences of pleasure, mood, and movement. In these same studies, researchers compared the damage to the dopamine system of methamphetamine users to that seen in patients with Parkinson's disease. Parkinson's disease is characterized by a progressive loss of dopamine neurons in brain regions that are involved in movement. Although the damage to the dopamine system was greater in the Parkinson's patients, the brains of former methamphetamine users showed similar patterns to that seen in Parkinson's disease. Scientists now believe that the damage to the dopamine system from long-term methamphetamine use may lead to symptoms of Parkinson's disease. (It should be noted that Parkinson's disease itself is not caused by drug use.) In support of this, research with laboratory animals has demonstrated that exposure to a single, high-dose of methamphetamine or prolonged exposure at low doses destroys up to fifty

percent of the dopamine-producing neurons in certain parts of the brain.

Methamphetamine also has widespread effects on other parts of the body. It can cause high blood pressure, arrhythmias, chest pain, shortness of breath, nausea, vomiting, and diarrhea. It can also increase body temperature, which can be lethal in overdose situations.

The following activities, when used along with the magazine on methamphetamine, will help explain to students how this substance changes the brain and the body.





# Methamphetamine



## OBJECTIVE

- ★ **The student will become more familiar with the neuroscience concepts and terminology associated with the effects of methamphetamine on the brain and body.**

## OBJECTIVE

- ★ **The student will become familiar with how methamphetamine changes brain functioning and the potential long-term implications of these changes.**

## OBJECTIVE

- ★ **The student will learn more about how methamphetamine and other drugs change the way the brain works.**

## METHAMPHETAMINE ACTIVITY ONE

The students will complete the methamphetamine Word Search. The teacher will then review the words and have the students discuss how the terms relate to methamphetamine abuse. A copy of the Word Search and Word Search Solution is included in the guide.

## METHAMPHETAMINE ACTIVITY TWO

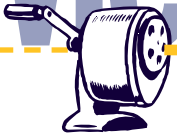
Review the effects of methamphetamine on the brain, paying particular attention to its effects on the neurotransmitter dopamine. Have students break into small groups. Ask each group to write and perform a play that demonstrates how methamphetamine changes the normal functioning of neurons that contain dopamine. Discuss with students how these changes can result in long-term impairment of dopamine function and the implications of this impairment (e.g., inability to feel pleasure, symptoms of Parkinson's Disease).

## METHAMPHETAMINE ACTIVITY THREE

Review with students the function of various brain areas (e.g., amygdala, hippocampus, cerebellum, etc.). Have students break into small groups and assign each group one brain area. Ask the students to discuss how methamphetamine or other drugs might affect their brain area. Then have students discuss the function of this brain area and how changing it through drug use might change how a person feels, acts, remembers, learns, etc. Have each group present a summary of their discussions to the entire class. For extra credit, have students discuss and present how brain imaging techniques (such as PET, or Positron Emission Tomography) help researchers to examine how drugs act in the brains of living human subjects.



# Methamphetamine



## WORD SEARCH

M	N	R	O	E	T	T	N	A	L	U	M	I	T	S
F	E	O	L	A	Q	P	N	Z	L	N	O	N	T	N
E	U	T	G	N	S	O	F	T	E	I	O	J	U	O
P	R	P	H	I	X	R	O	U	M	N	Y	E	G	I
W	O	E	L	A	J	E	R	E	I	O	K	C	A	T
Q	T	C	T	R	M	O	S	N	H	T	R	T	W	A
U	R	E	A	B	N	P	O	I	D	O	A	E	S	N
P	A	R	V	A	A	A	H	O	I	R	S	D	M	I
M	N	Y	Z	N	L	R	P	E	D	E	E	P	S	C
F	S	O	Y	E	O	A	L	A	T	S	Y	R	C	U
E	M	S	B	U	M	N	I	R	K	A	V	T	I	L
T	I	L	T	I	I	O	N	T	L	P	M	U	U	L
G	T	G	N	R	T	I	C	E	A	G	G	I	S	A
B	T	E	P	O	O	A	S	I	H	V	U	B	N	H
J	E	F	E	N	P	K	W	H	C	X	R	Q	B	E
C	R	A	S	H	N	I	E	T	I	R	D	N	E	D

Methamphetamine  
Crystal  
Speed  
Paranoia  
Dopamine  
Synapse  
Stimulant  
Brain

Neurotransmitter  
Axon  
Receptor  
Crash  
Hallucinations  
Serotonin  
PET

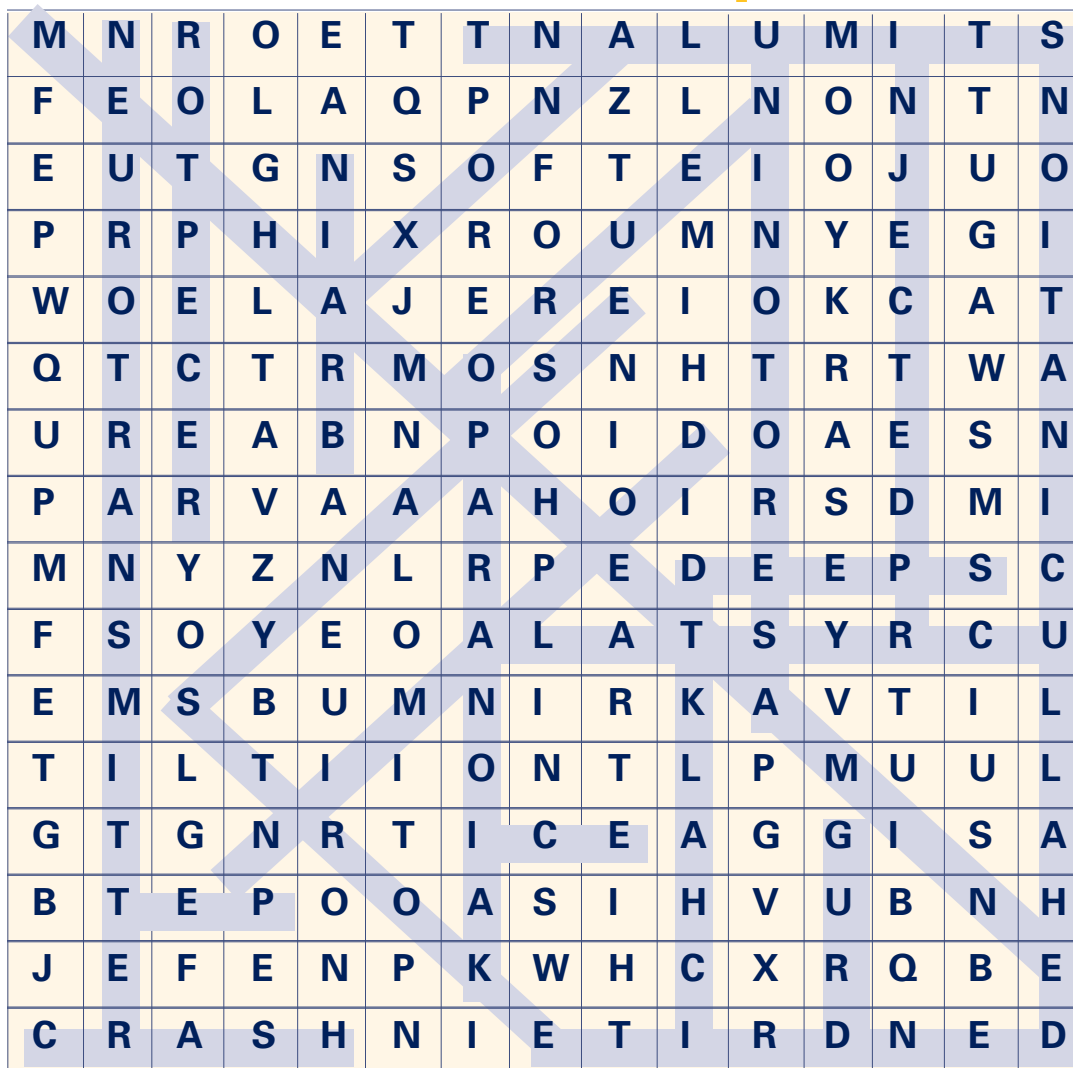
Neuron  
Stroke  
Dendrite  
Drug  
Ice  
Chalk  
Injected

# Methamphetamine



## WORD SEARCH

SOLUTION



Methamphetamine  
Crystal  
Speed  
Paranoia  
Dopamine  
Synapse  
Stimulant  
Brain

Neurotransmitter  
Axon  
Receptor  
Crash  
Hallucinations  
Serotonin  
PET

Neuron  
Stroke  
Dendrite  
Drug  
Ice  
Chalk  
Injected

# General

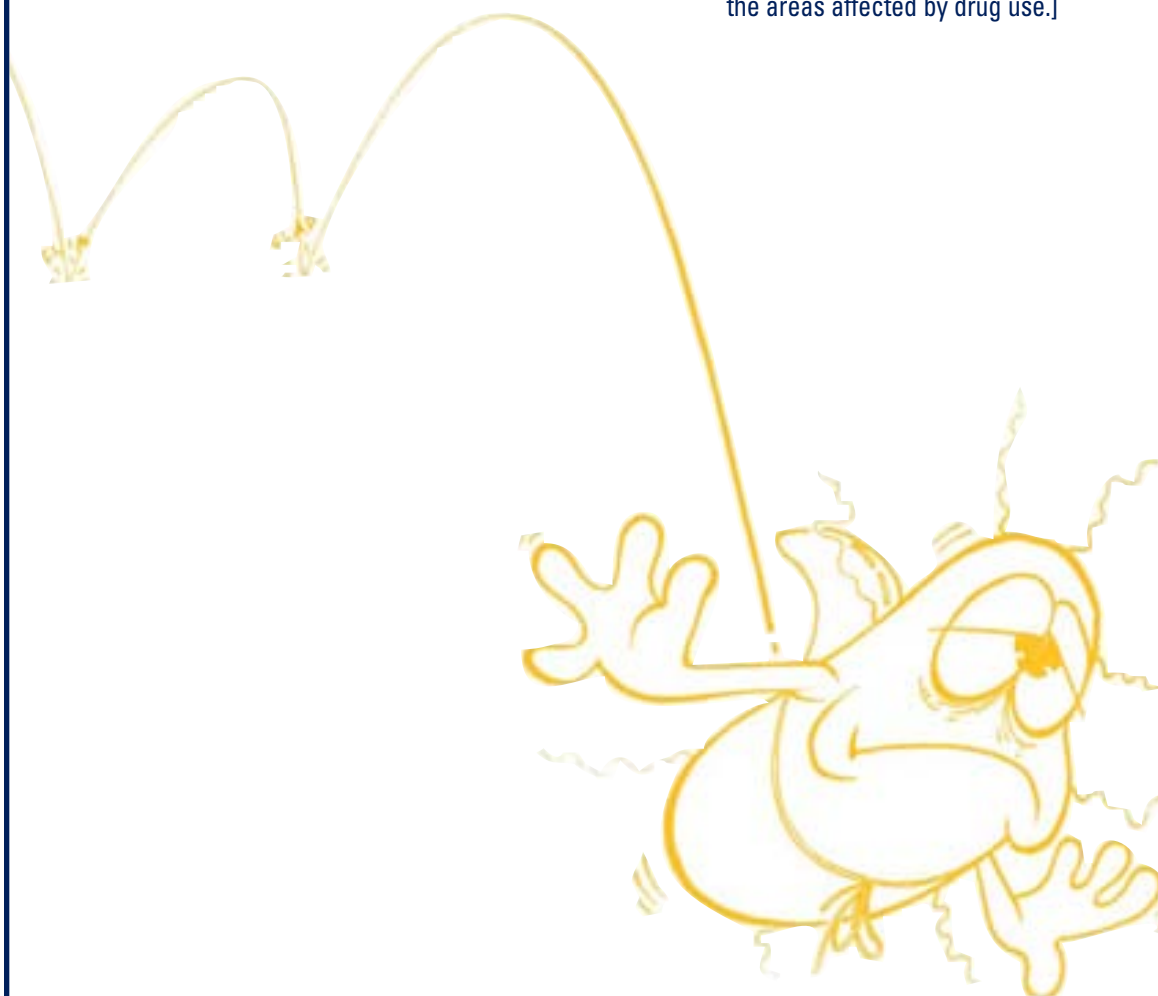


## OBJECTIVES

- ★ **The student will learn the names of the lobes, cortical areas, and structures in the brain.**
- ★ **The student will learn the specific brain areas and structures affected by drug use.**

## UNIFYING ACTIVITY

Students will use reference materials to create three brain maps: one which shows the different regions of the brain, one which shows the areas within the cortex, and one which displays different brain structures. For all of the drugs discussed, students will “mark” their maps (for example, using stickers or colored markers) to specify the areas affected by substance use. [Note: If materials such as molding clay or plaster are available, have groups of students also create three-dimensional brain models, and use small, separate strands of Christmas lights to “mark” the areas affected by drug use.]



# Resources

## **National Institute on Drug Abuse**

301-443-6245  
<http://www.drugabuse.gov>

## **National Clearinghouse for Alcohol and Drug Information**

1-800-729-6686 or 1-800-487-4889 (TDD)  
<http://www.health.org>

## **Office of Science Education**

**National Institutes of Health**  
301-402-2828

## **Society for Neuroscience**

### **Education Program**

202-462-6688  
<http://www.sfn.org>

## **Society for Neuroscience Brain Briefings**

<http://www.sfn.org/briefings>  
This site provides access to Society for Neuroscience publications covering topics such as addiction, opiate receptors, and the effects of various drugs on the brain and behavior.

## **Society for Neuroscience Brain Backgrounders**

<http://www.sfn.org/backgrounders/>  
This site provides an online series of articles that answer basic neuroscience questions.

## **National Families in Action Online**

<http://www.nationalfamilies.org>  
This site includes the latest scientific information about the effects of drugs on the brain and body, and allows the visitor to ask neuroscience experts questions about drugs.

## **Neurosciences on the Internet**

<http://www.neuroguide.com>  
This site includes information on basic neurosciences, including recent journal articles that discuss drugs of abuse.

## **Wisconsin/Michigan State Brain Collections**

<http://www.neurophys.wisc.edu>  
This site includes a visual tour of photos and brain sections of mammalian brains, with related information on brain anatomy, brain functions, and neuroanatomy.

## **Eisenhower National Clearinghouse**

<http://www.enc.org/>  
This site provides a source of published materials for K-12 math and science teachers.

## **Brain Anatomy**

<http://www.exploratorium.edu/memory/braindissection/index.html>  
This site provides images of a sheep brain dissection.

## **Science in the News**

<http://whyfiles.org/>  
This site provides articles on science items that have been in the news. Several articles on nicotine addiction can be found through the Search button.

## Internet Sites

## **National Institute on Drug Abuse**

<http://www.drugabuse.gov>  
<http://teens.drugabuse.gov>  
This site contains information on drugs of abuse, NIDA publications and communications, agency events, and links to other drug-related Internet sites.

## **Sara's Quest**

<http://www.sarasquest.org>  
Join Sara Bellum as she explores how drugs affect the brain. This site features questions related to the Mind Over Matter materials. Students can join Sara's Quest Club and receive a free poster.

## **National Clearinghouse for Alcohol and Drug Information**

<http://www.health.org>  
This site includes information on publications, calendars, and related Internet sites, as well as a youth site.

## **Office of Science Education**

### **National Institutes of Health**

<http://science-education.nih.gov>  
This site provides a "one-stop shopping service" for people looking for information from the National Institutes of Health. It contains sections for teachers, students, and the public.

## **Neuroscience for Kids**

<http://faculty.washington.edu/chudler/introb.html>  
This site includes answers to commonly asked questions about the brain and neuroscience, with information on brain and spinal cord anatomy and physiology, neurotransmission, and the effects of specific drugs on the nervous system.

## **Dana Alliance for Brain Initiatives**

<http://www.dana.org/brainweb>  
This site includes resources for people interested in brain diseases and disorders, with specific sections devoted to alcohol and drug abuse.



# Reading List

**Brain Facts: A primer on the Brain and Nervous System, Society for Neuroscience, 1993.**

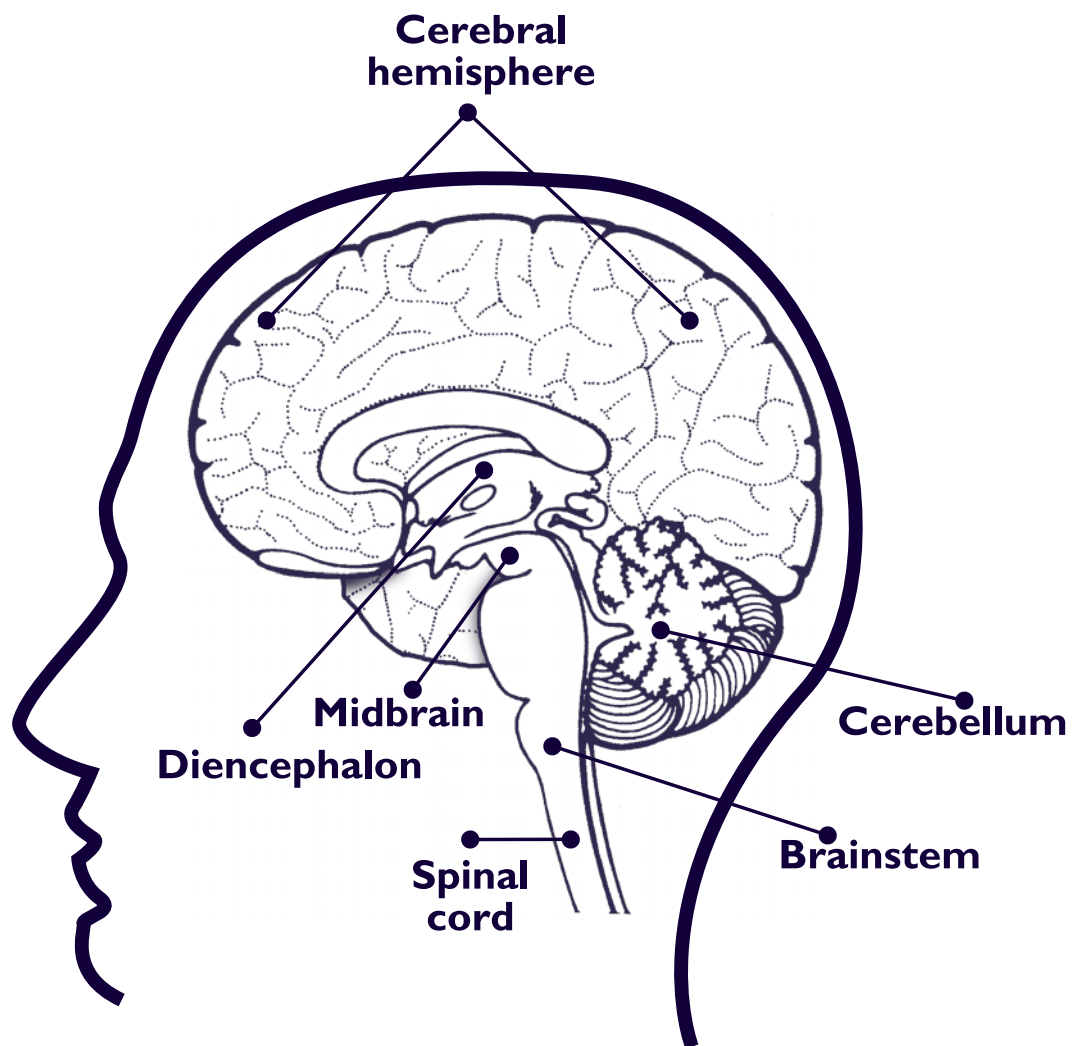
**How your Brain Works, by Anne D. Novitt-Morino, M.D., Ziff-Davis Press, 1995.**

**Explorations in Neuroscience for Children and Adults, Baylor College of Medicine, WOW Publications, Inc., 1997.**



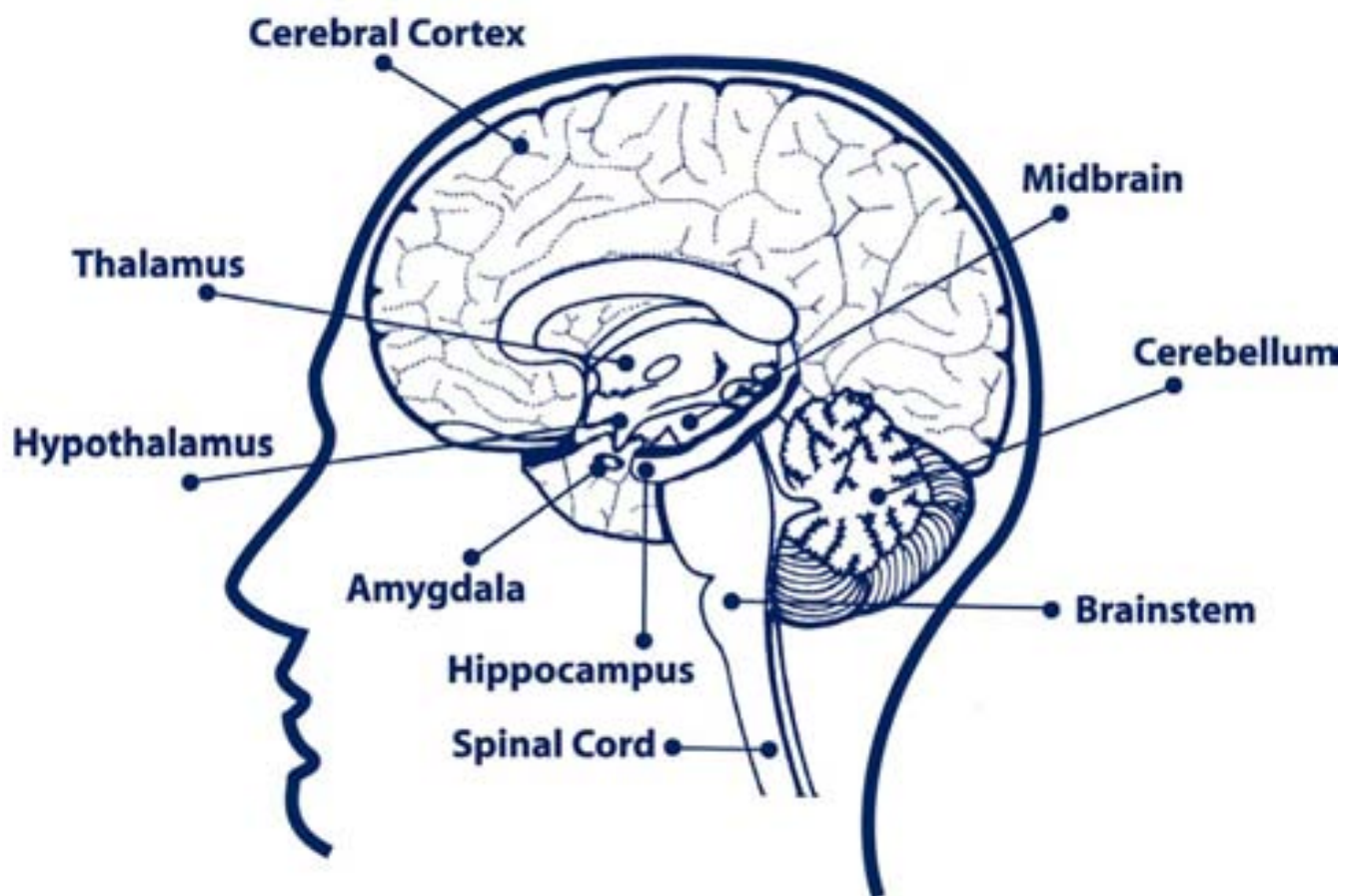


**Figure 1**

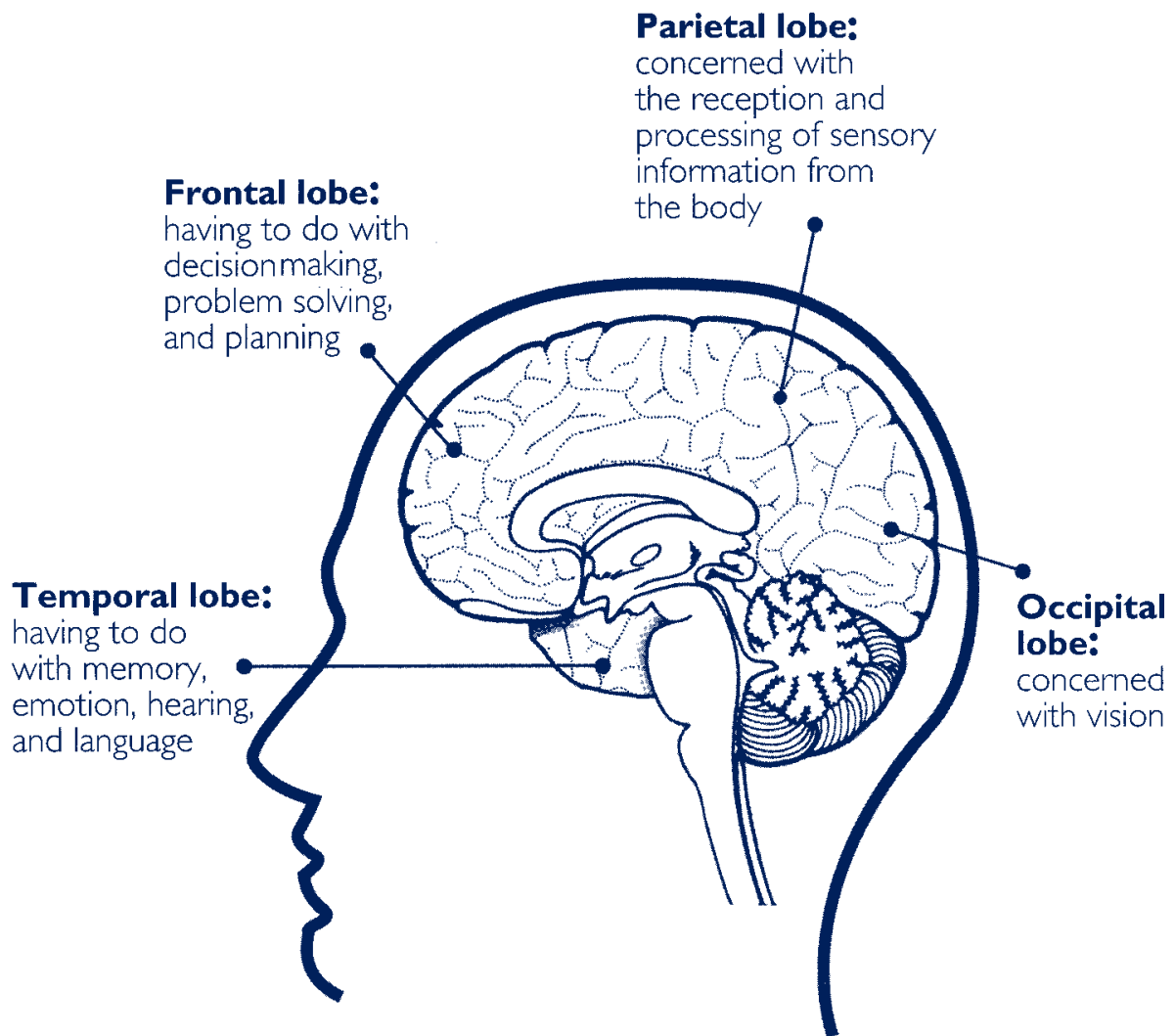




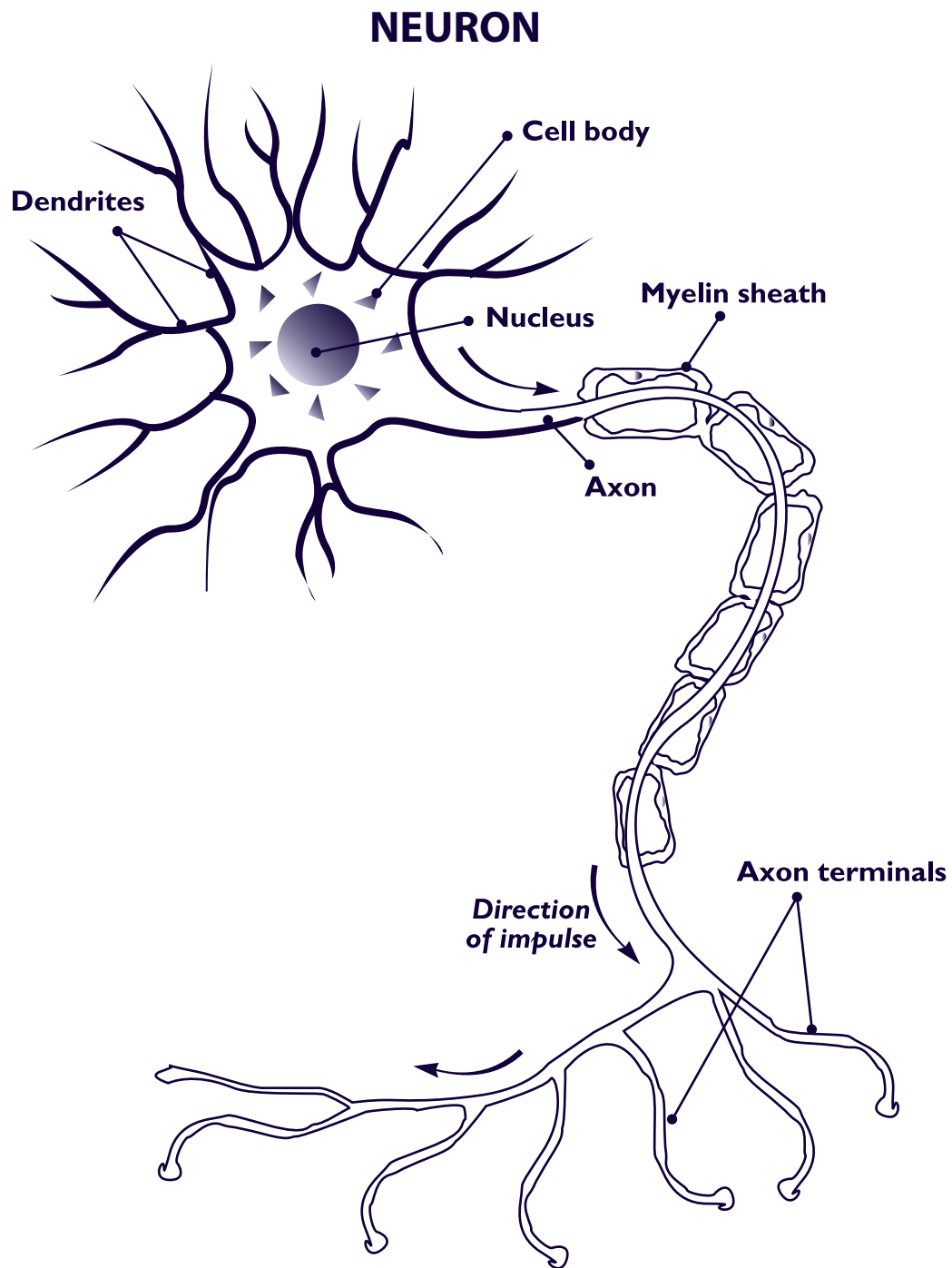
**Figure 2**



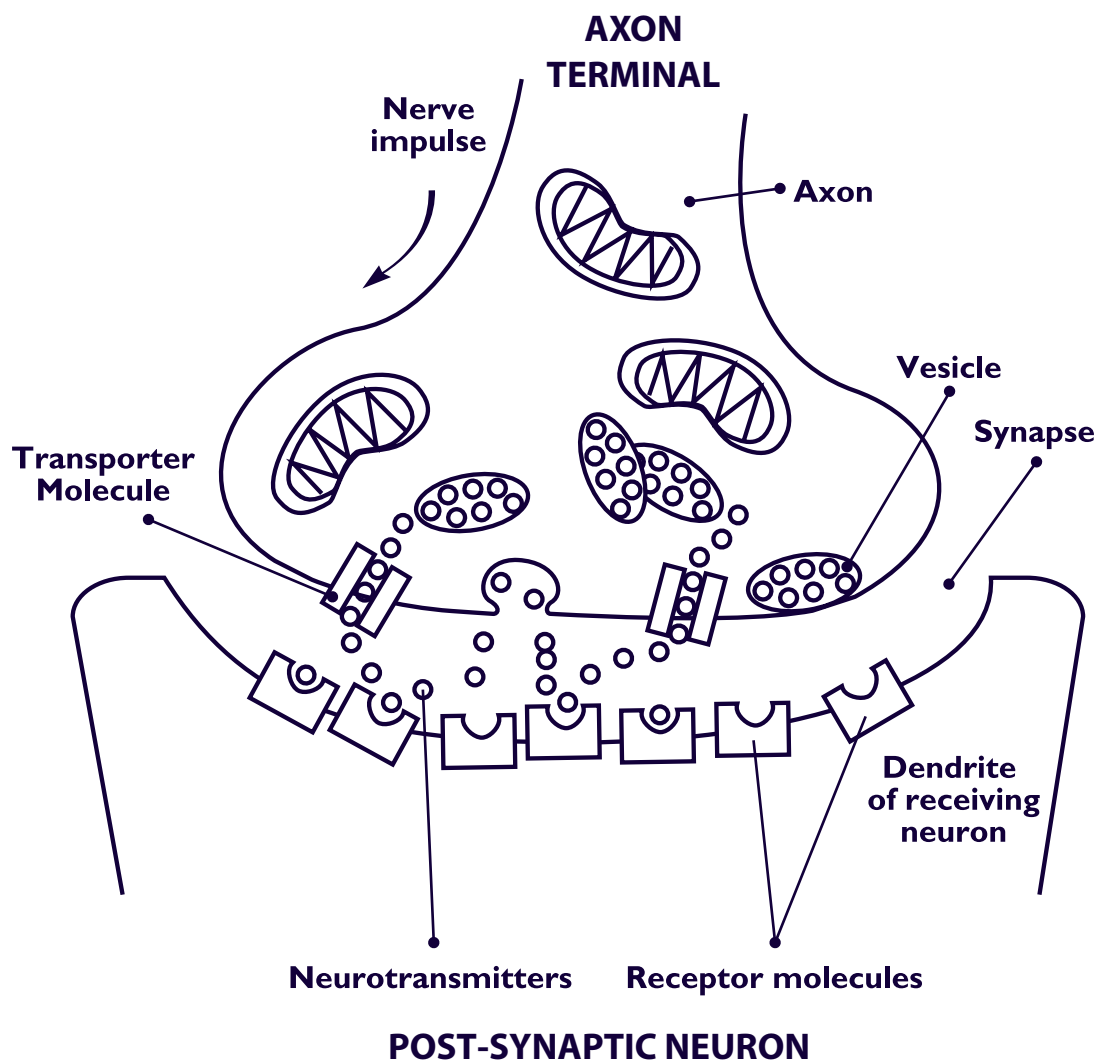
# Figure 3



**Figure 4**

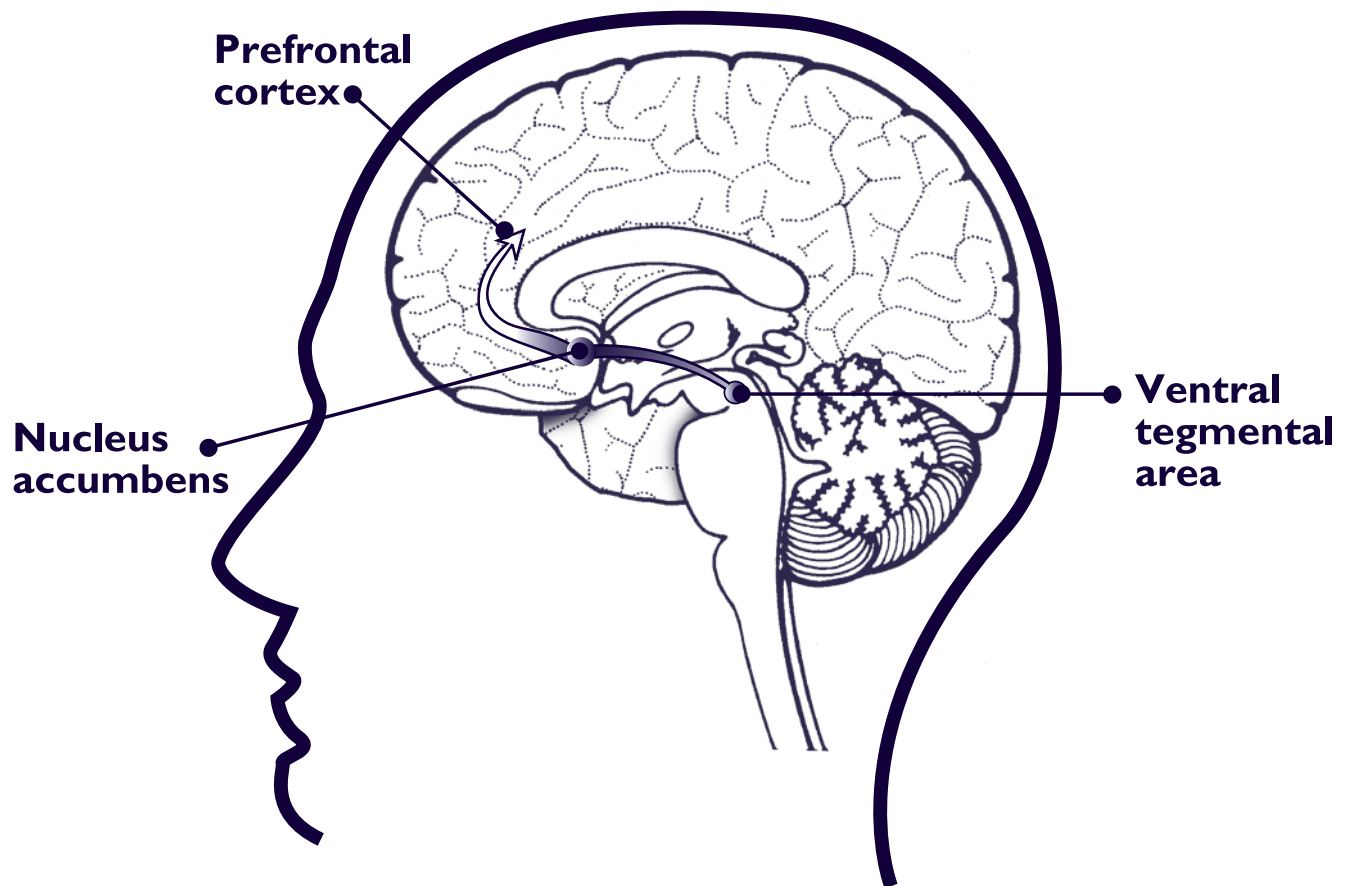


**Figure 5**

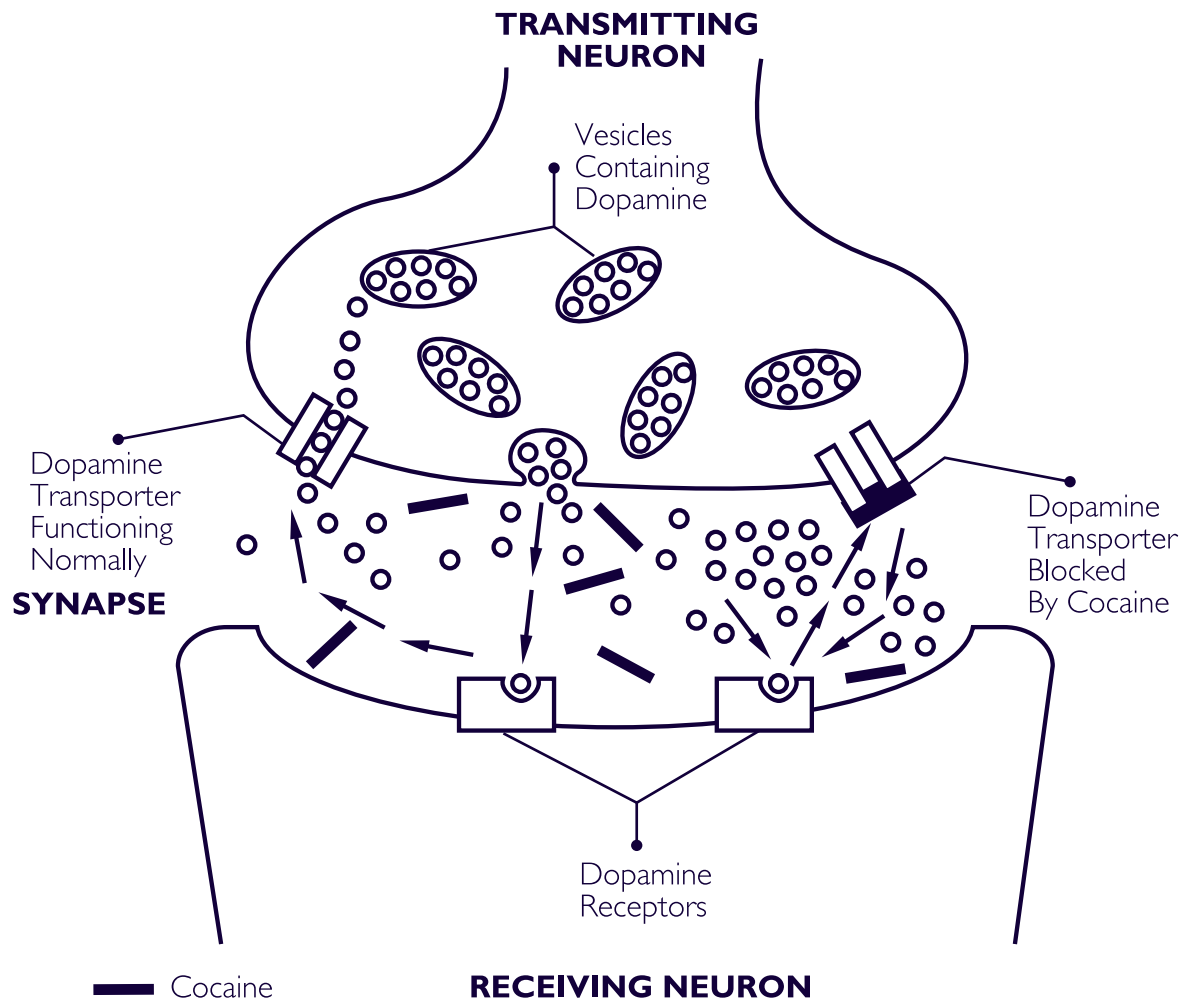


**Figure 6**

**REWARD CIRCUIT**



**Figure 7**





**[www.sarasquest.org](http://www.sarasquest.org)**

This site features questions related to the Mind Over Matter materials. Students can join Sara's Quest Club and receive free posters.





**NIH**

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# The Brain's Response to Anabolic Steroids

Hi, my name's Sara Bellum. Welcome to my magazine series exploring the brain's response to drugs. In this issue, we'll investigate the fascinating facts about anabolic steroids.

Anabolic steroids are artificial versions of a hormone that's in all of us—testosterone. (That's right, testosterone is in girls as well as guys.) Testosterone not only brings out male sexual traits, it also causes muscles to grow.

Some people take anabolic steroid pills or injections to try to build muscle faster. ("Anabolic" means growing or building.)

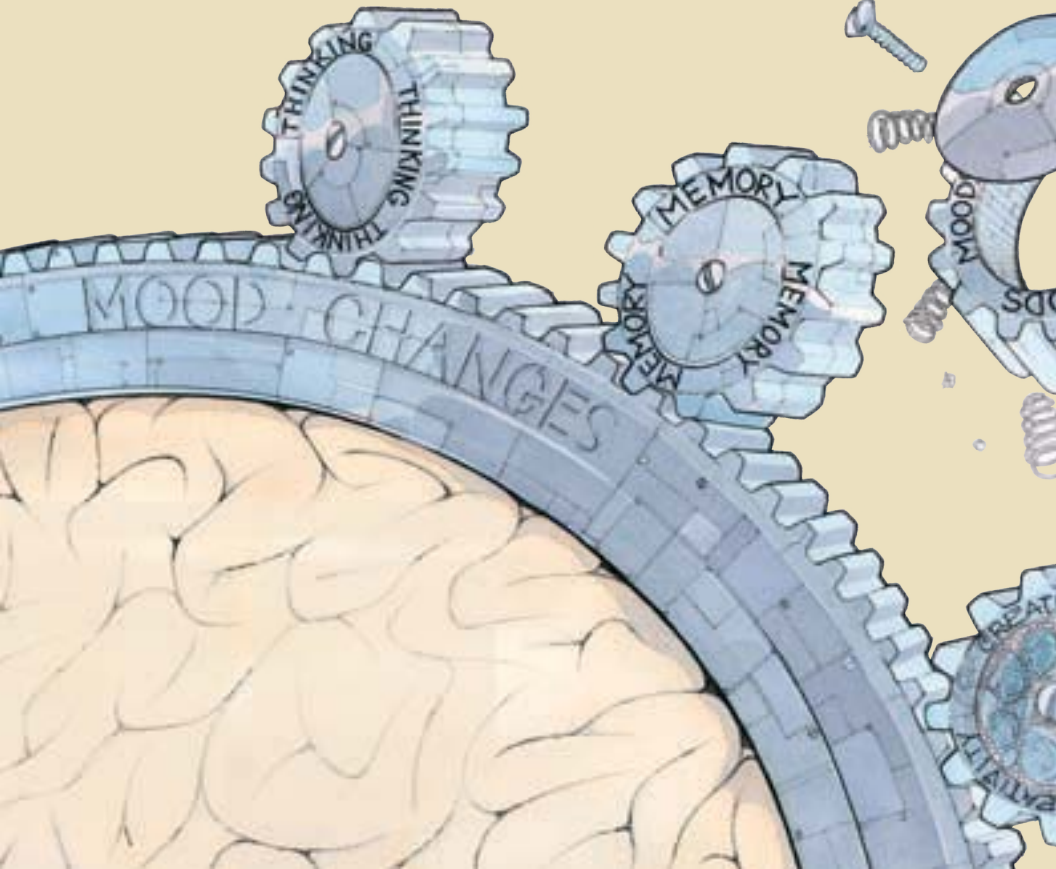
But these steroids also have other effects. They can cause changes in the brain and body that increase risks for illness, and they may also affect moods.

**National Institute on Drug Abuse**



**But while anabolic steroids can make some people look stronger on the outside, they may create weaknesses on the inside.**

For example, anabolic steroids are bad for the heart—they can increase fat deposits in blood vessels, which can cause heart attacks and strokes. They may also damage the liver. Steroids can halt bone growth—which means that a teenage steroid user may not grow to his/her full adult height.



# Anabolic Steroids Affect the Brain

Scientists are still learning about how anabolic steroids affect the brain, and in turn, behavior. Research has shown that anabolic steroids may trigger aggressive behavior in some people. This means that someone who abuses anabolic steroids may act mean to people they're normally nice to, like friends and family, and they may even start fights. Some outbursts can

be so severe they have become known in the media as "roid rages." And when a steroid abuser stops using the drugs, they can become depressed, even suicidal. Researchers think that some of the changes in behavior may be caused by hormonal changes that are caused by steroids, but there is still a lot that is not known.

## Anabolic Steroids Can Confuse the Brain and Body

Your body's testosterone production is controlled by a group of nerve cells at the base of the brain, called the hypothalamus. The hypothalamus also does a lot of other things. It helps control appetite, blood pressure, moods, and reproductive ability.

Anabolic steroids can change the messages the hypothalamus sends to the body. This can disrupt normal hormone function.

In guys, anabolic steroids can interfere with the normal production of testosterone. They can also act directly on the testes and cause them to shrink. This can result in a lower sperm count. They can also cause an irreversible loss of scalp hair.

In girls, anabolic steroids can cause a loss of the monthly period by acting on both the hypothalamus and reproductive organs. They can also cause loss of scalp hair, growth of body and facial hair, and deepening of the voice. These changes can also be irreversible.



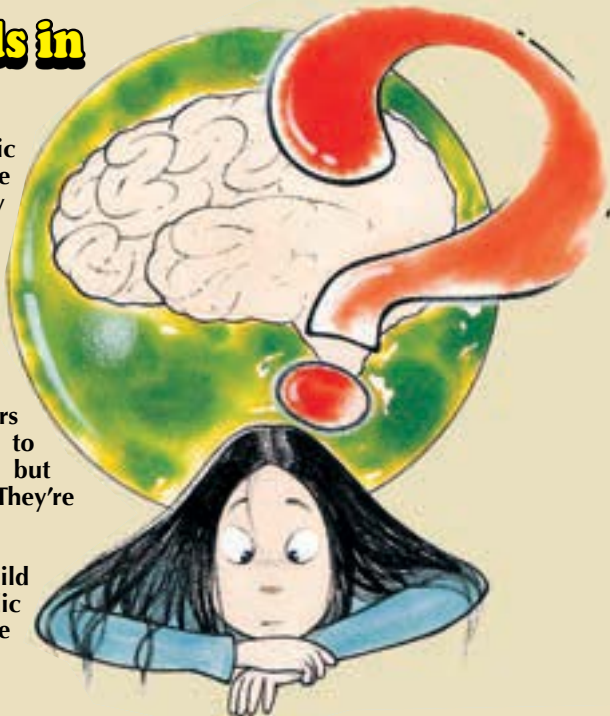


# Anabolic Steroids in Medicine

Doctors never prescribe anabolic steroids for building muscle in young, healthy people. (Try push-ups instead!) But doctors sometimes prescribe anabolic steroids to treat some types of anemia or disorders in men that prevent the normal production of testosterone.

You may have heard that doctors sometimes prescribe steroids to reduce swelling. This is true, but these aren't anabolic steroids. They're corticosteroids.

Since corticosteroids don't build muscles the way that anabolic steroids do, people don't abuse them.



## STEROIDS

**True  
or False**

- 1) Anabolic steroids can affect the hypothalamus.
- 2) Anabolic steroids strengthen the immune system.
- 3) Anabolic steroids can cause males' breasts to grow and females' breasts to shrink.

1) True, 2) False, 3) True.

## The Search Continues

There's still a whole lot that scientists don't know about the effects of anabolic steroids on the brain. Maybe someday you'll make the next big discovery.

Until then, join me—Sara Bellum—in the other magazines in my series, as we explore how drugs affect the brain and nervous system.



For more information, visit:

**[www.teens.drugabuse.gov](http://www.teens.drugabuse.gov)**

To learn more about anabolic steroids and other drugs of abuse, or to order materials on these topics, free of charge, in English or Spanish, **visit the NIDA Web site at [www.drugabuse.gov](http://www.drugabuse.gov) or contact the DrugPubs Research Dissemination Center at 877-NIDA-NIH (877-643-2644; TTY/TDD: 240-645-0228).**



# The Brain's Response to Cocaine

Hi, my name's Sara Bellum. Welcome to my magazine series exploring the brain's response to drugs. In this issue, we'll investigate the fascinating facts about the drug cocaine, which is considered a stimulant.

Have you eaten any chocolate or drunk any soda lately? If you have, there's a good chance you gave your body a dose of a stimulant—caffeine, which is also in coffee.

Eating or drinking a large amount of caffeine can make you feel jittery, nervous, or energetic. That's because caffeine—like any stimulant—changes the way your brain works.

But caffeine is just a mild example of a stimulant. Many other stimulant drugs are much stronger—and some are illegal and very dangerous.

Cocaine is made from the leaf of the coca plant. It often comes in the form of a white powder that some people inhale through their nose. Another form of cocaine, known as crack, can be smoked.



**National Institute on Drug Abuse**

# Miscommunication in the Brain

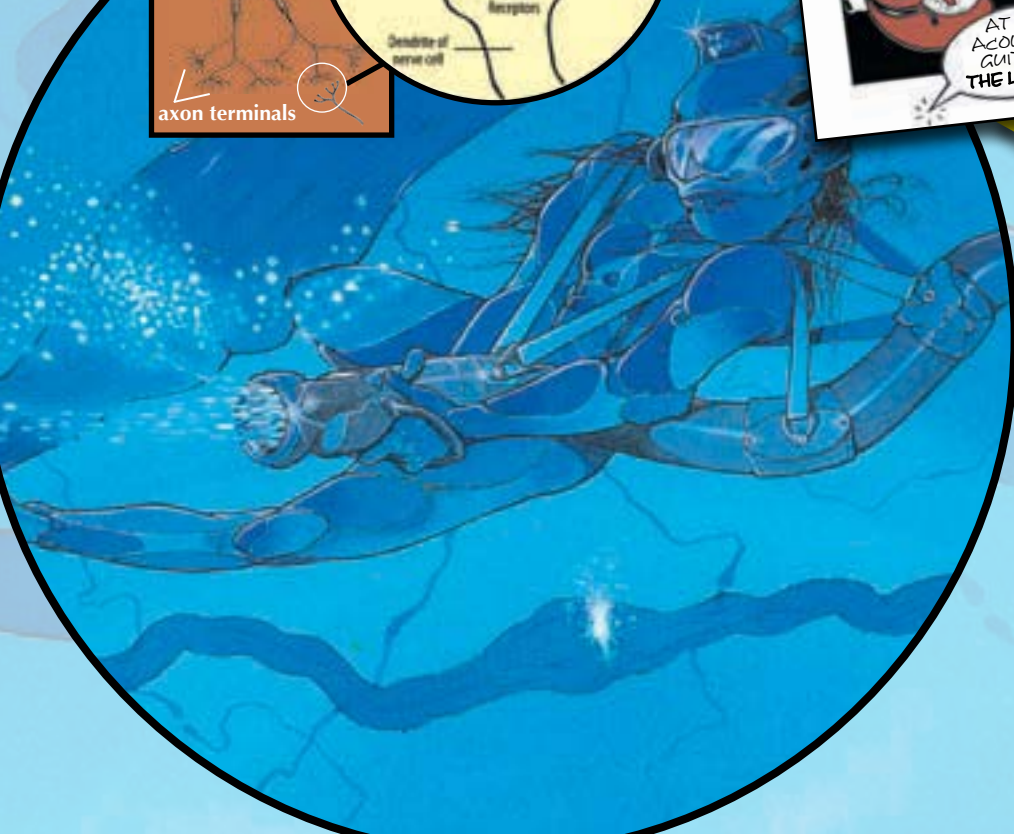
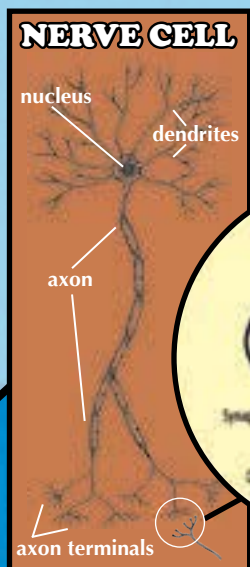
Cocaine changes the way the brain works by changing the way nerve cells communicate. Nerve cells, called neurons, send messages to each other by releasing special chemicals called neurotransmitters. Neurotransmitters are able to work by attaching to key sites on neurons called receptors.

One of the neurotransmitters affected by cocaine is called dopamine. Dopamine is released by neurons in the limbic system—the part of the brain that controls feelings of pleasure.

Normally, once dopamine has attached to a nerve cell's receptor and caused a change in the cell, it's pumped back to the neuron that released it. But cocaine blocks the pump, called the dopamine transporter. Dopamine then builds up in the gap (synapse) between neurons.

The result: dopamine keeps affecting a nerve cell after it should have stopped.

That's why someone who uses cocaine feels an extra sense of pleasure for a short time.





# Cocaine Can Change the Way the Brain Works

Although cocaine may make someone feel pleasure for a while, later it can take away a person's ability to feel pleasure from natural rewards, like a piece of chocolate or a good time with friends. Research suggests that long-term cocaine use may reduce the amount of dopamine or number of dopamine receptors in the brain. When this happens, nerve cells need

more dopamine to function normally—or more drug to be able to feel pleasure.

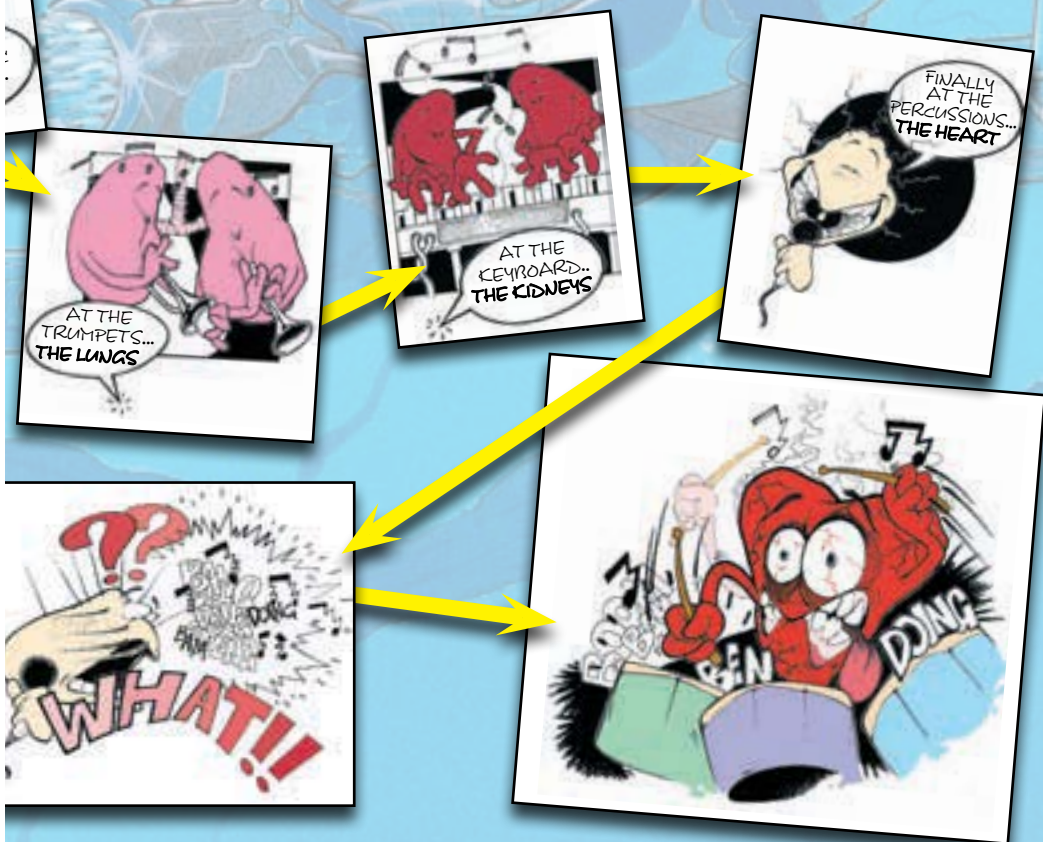
If a long-term user of cocaine stops taking the drug, the person feels tired and sad, and experiences strong craving for the drug. These feelings can last for a long time, until the brain (and the person) recovers from addiction.

## Cocaine Tightens Blood Vessels

Cocaine causes the body's blood vessels to become narrow, constricting the flow of blood. This is a problem. It forces the heart to work harder to pump blood through the body. (If you've ever tried squeezing into a tight pair of pants, then you know how hard it is for the heart to pump blood through narrowed blood vessels.)

When the heart works harder, it beats faster. It may work so hard that it temporarily loses its natural rhythm. This is called fibrillation, and it can be very dangerous because it stops the flow of blood through the body.

Many of cocaine's effects on the heart are actually caused by cocaine's impact on the brain—the body's control center.

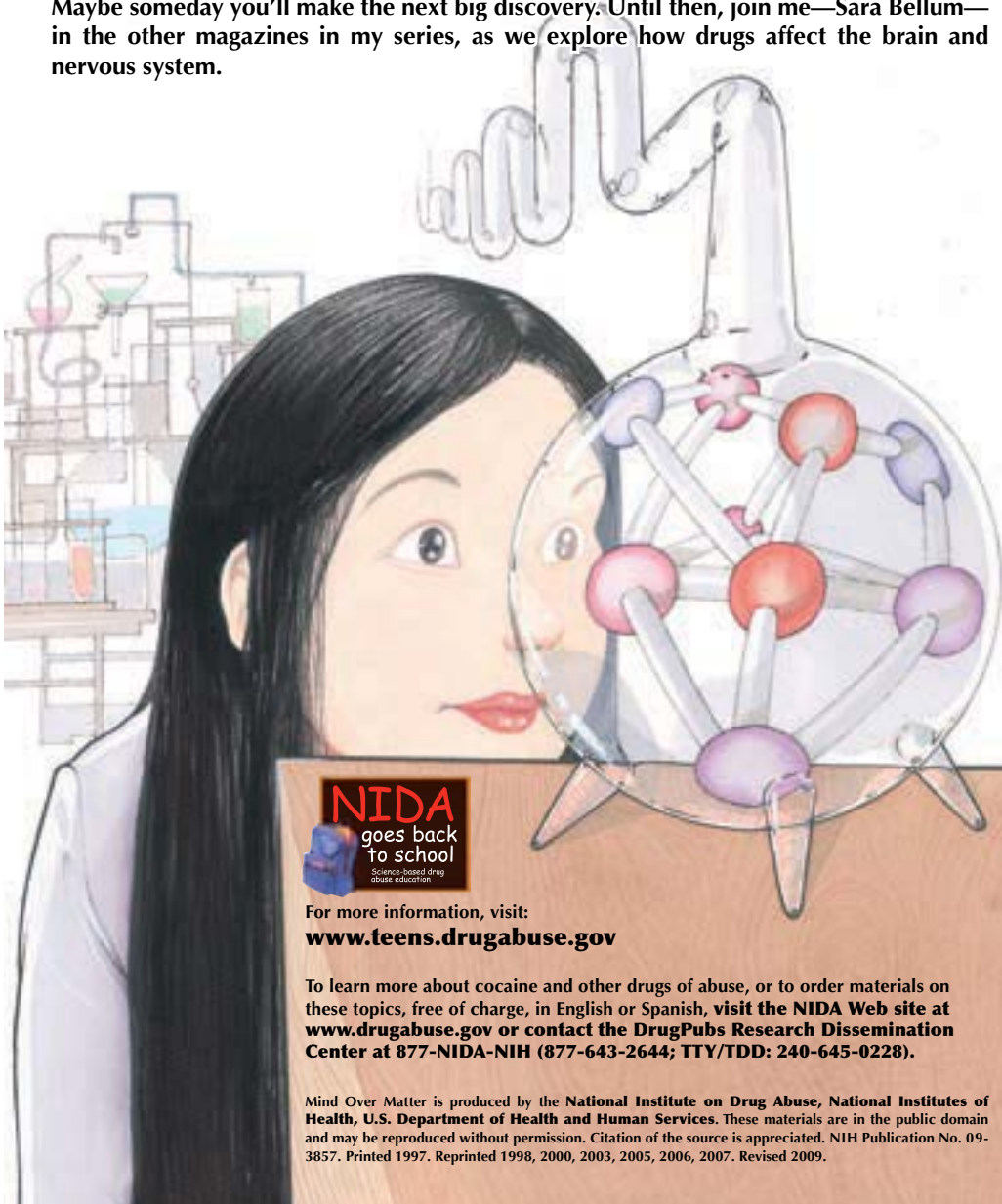


# Scientists Discover Answers

Fortunately, scientists have figured out how cocaine works, which will help them discover treatments for cocaine addiction. Right now there are talk therapies that can help, but someday there may be medications as well.

## The Search Continues

There's still a lot that scientists don't know about the effects of cocaine on the brain. Maybe someday you'll make the next big discovery. Until then, join me—Sara Bellum—in the other magazines in my series, as we explore how drugs affect the brain and nervous system.



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# **The Brain's Response to Hallucinogens**

Hi, my name's Sara Bellum. Welcome to my magazine series exploring the brain's response to drugs. In this issue, we'll investigate the fascinating facts about hallucinogens.

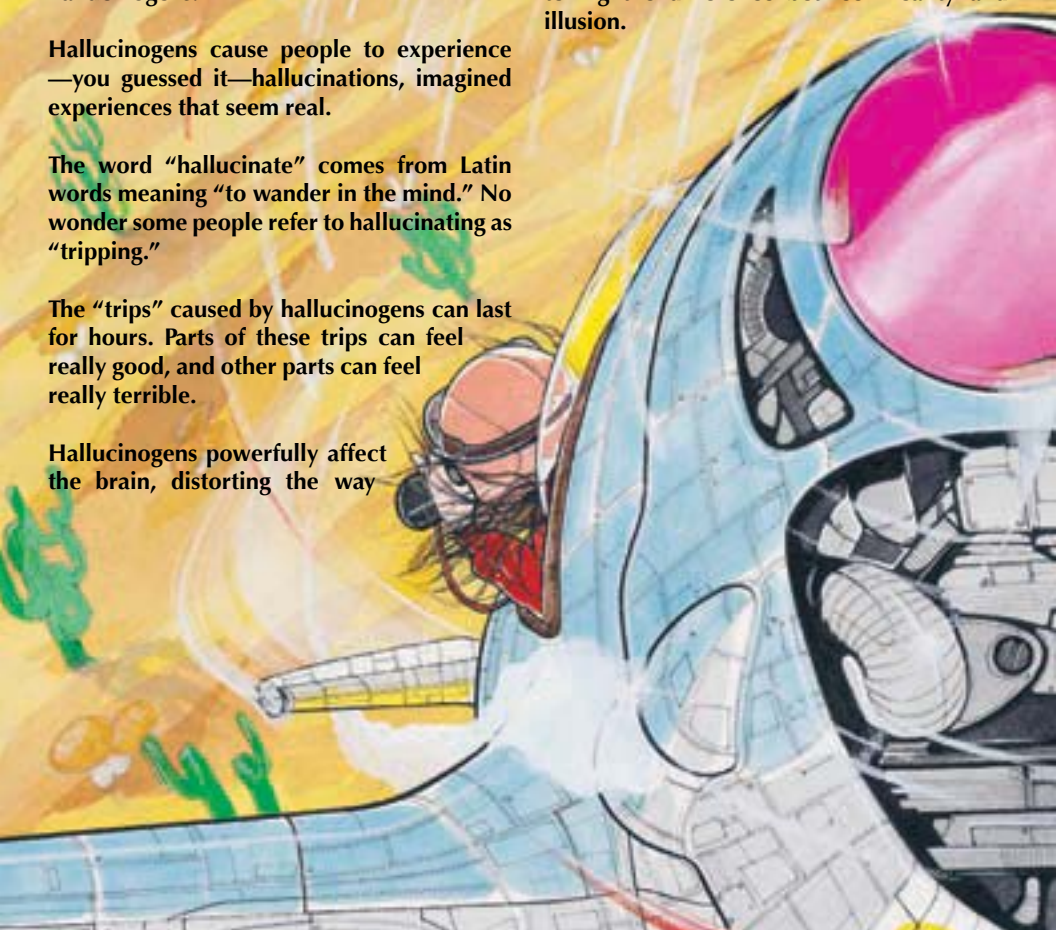
Hallucinogens cause people to experience—you guessed it—hallucinations, imagined experiences that seem real.

The word “hallucinate” comes from Latin words meaning “to wander in the mind.” No wonder some people refer to hallucinating as “tripping.”

The “trips” caused by hallucinogens can last for hours. Parts of these trips can feel really good, and other parts can feel really terrible.

Hallucinogens powerfully affect the brain, distorting the way

our five senses work and changing our impressions of time and space. When people use these drugs a lot they may have a hard time concentrating, communicating, or telling the difference between reality and illusion.



**National Institute on Drug Abuse**

# Where Do Hallucinogens Come From?

Some hallucinogens can be found in plants. Mescaline comes from a cactus called peyote. And certain mushrooms, also known as “magic” mushrooms, are hallucinogens.

But many hallucinogens are chemicals that don’t occur in nature. Some examples are:

- LSD, also called acid
- MDA, also called the “love drug,” related to the stimulant amphetamine
- MDMA, known as ecstasy, also related to amphetamine
- PCP, often called angel dust

## How Hallucinogens Affect Your Senses

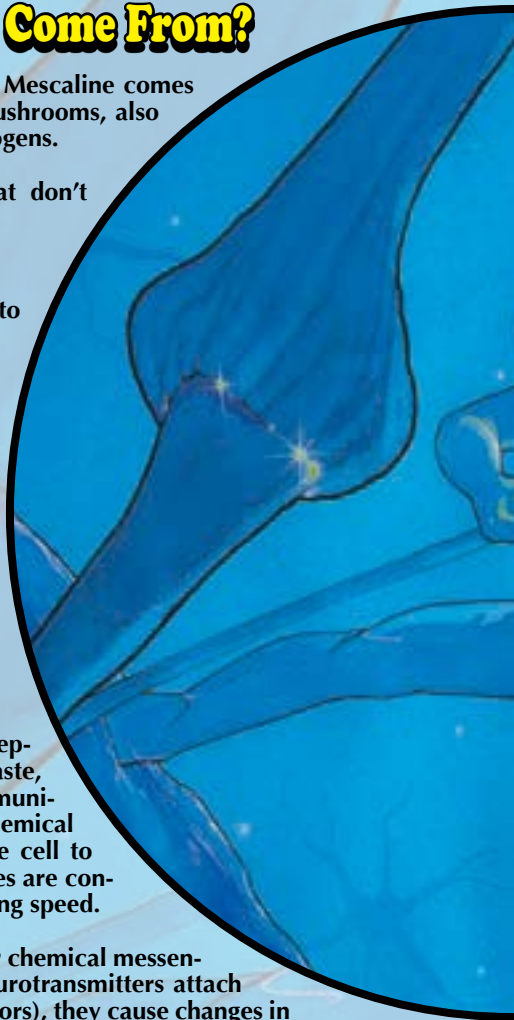
Your brain controls all of your perceptions—the way you see, hear, smell, taste, and feel. How does your brain communicate with the rest of your body? Chemical messengers transmit information from nerve cell to nerve cell in the body and the brain. Messages are constantly being sent back and forth with amazing speed.

Your nerve cells are called neurons, and their chemical messengers are called neurotransmitters. When neurotransmitters attach to special places on nerve cells (called receptors), they cause changes in the nerve cells.

This communication system can be disrupted by chemicals like hallucinogens, and the results are changes in the way you sense the world around you.

## How MDMA and MDA Affect Your Brain

MDMA and MDA cause neurons to release a neurotransmitter called serotonin, which can overactivate serotonin receptors. Serotonin is important to many types of nerve cells, including cells that receive sensory information and cells that control mood, sleep, and memory. Animal studies have taught us that MDMA and MDA can damage fibers from these nerve cells. And even though some of these fibers grow back, they don’t grow back normally. They can wind up in places where they don’t belong.

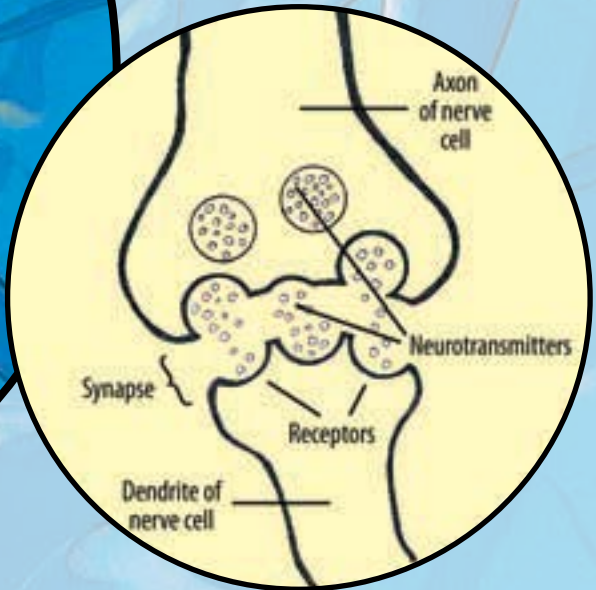




## Actions of PCP in the Brain

PCP prevents the actions normally caused when a neurotransmitter, called glutamate, attaches to its receptor in the brain. It also disrupts the actions of other neurotransmitters.

This drug's effects are very unpredictable. For example, it may make some people hallucinate and become aggressive, while others may become drowsy and passive. It is also addictive.



## LSD: The Most Commonly Used Hallucinogen

LSD causes its effects mainly by activating one type of receptor for serotonin. Because serotonin has a role in many important functions, LSD use can have many effects. These may include sleeplessness, trembling, and raised heart rate and blood pressure.

LSD users may feel several emotions at once (including extreme terror), and their

senses may seem to get crossed—giving the feeling of hearing colors and seeing sounds.

Even a tiny speck of LSD can trigger these effects. And LSD has an unusual “echo”: many users have flashbacks—sudden repetitions of their LSD experiences—days or months after they stop using the drug.

Have your perceptions been

# ALTERED?

Hallucinogens can change the way you see things. The experience is a little like looking at the optical illusion below.

## The Search Continues

The truth is, there's still a whole lot that scientists don't know about the effects of hallucinogens on the brain. Maybe someday you'll make the next big discovery.

Until then, join me—Sara Bellum—in the other magazines in my series, as we explore how drugs affect the brain and nervous system.



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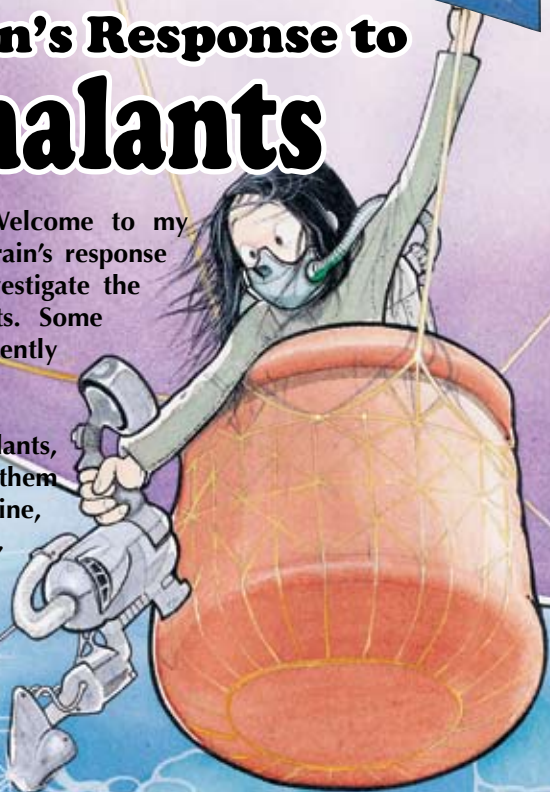
# **The Brain's Response to Inhalants**

Hi, my name's Sara Bellum. Welcome to my magazine series exploring the brain's response to drugs. In this issue, we'll investigate the fascinating facts about inhalants. Some of this information was only recently discovered by leading scientists.

Maybe you haven't heard of inhalants, but you probably come across them pretty often. Hair spray, gasoline, spray paint -- they are all inhalants, and so are lots of other everyday products.

Many inhalants have a strong smell. Some people inhale the vapors on purpose. That's why they're called "inhalants."

Why would anyone do this? Because the chemicals in these vapors can change the way the brain works, and those changes can make people feel very happy for a short time.




**National Institute on Drug Abuse**





**Beyond  
the Brain**

# They Don't Go Away When You Exhale




Inhalant vapors often contain more than one chemical. Some leave the body quickly, but others are absorbed by fatty tissues in the brain and nervous system. They can stay there for a long time.

One of these fatty tissues is myelin -- a protective cover that surrounds many of the body's nerve cells (neurons). Nerve cells in your brain and spinal cord are sort of like "Command Central" for your body. They send and receive messages that control just about everything you think and do.

If you picture nerve cells as your body's electrical wiring, then think of myelin as the rubber insulation that protects an electrical cord.

One problem with inhalant use over the long term is that the chemicals can break down myelin. And if myelin breaks down, nerve cells may not be able to transmit messages.



One reason scientists are so interested in inhalants is that these chemicals affect the body in lots of ways. While some effects are due to changes in the brain, others are direct actions on other parts of the body, such as the circulatory system.

Did you know that some inhalants directly increase the size of blood vessels, allowing more blood to flow through? And some inhalants can make the heart beat faster. This can be a serious problem, especially if someone inhales butane gas.

Butane, found in cigarette lighters and refills, makes the heart extra sensitive to a chemical that carries messages from the

nervous system to the heart. This chemical, noradrenaline, tells the heart to beat faster when you're in a stressful situation -- like if something suddenly scares you.

If the heart becomes too sensitive to noradrenaline, a normal jolt of it may cause the heart to temporarily lose its rhythm and stop pumping blood through the body. Some inhalant users die this way. Inhalants can also cause death by suffocation. This occurs when the inhaled fumes take the place of oxygen in the lungs and the brain. This is known as Sudden Sniffing Death.

# Changes in the Brain

Damage from long term use of inhalants can slow or stop nerve cell activity in some parts of the brain.

This might happen in the frontal cortex, the part of the brain that solves complex problems and plans ahead. Or if inhalants get into the brain's cerebellum, which controls movement and coordination, they can make someone move slowly or clumsily.

Studies show that neurons in a part of the brain called the hippocampus can also be damaged by inhalants. The damage occurs because the cells don't get enough oxygen.

Since the hippocampus helps control memory, someone who repeatedly uses inhalants may lose the ability to learn new things, may not recognize familiar things, or may have a hard time keeping track of simple conversations.

## Can You Fill the Gaps

Sometimes, nerve cells that are damaged by inhalants may be able to repair themselves. The empty spaces in the following brain-related words represent damaged neurons. See if you can "repair" them by filling in the blanks to complete the words. (Hint: All the words are in this magazine.)

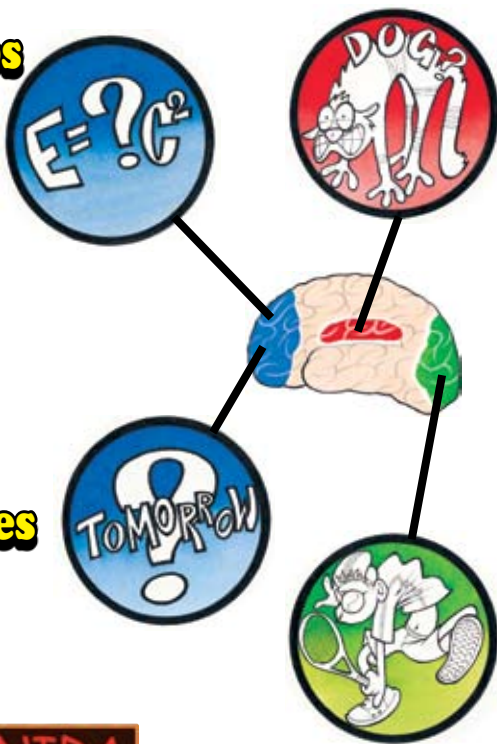
- 1) M . . L . .
- 2) . . U . O .
- 3) . . PP . . M . . S

## The Search Continues

The truth is, there's still a whole lot that scientists do not know about the effects of inhalants on the brain.

When scientists learn more about how various inhalants affect the brain, they may be able to develop treatments that prevent the damage inhalants can cause. Maybe someday you'll make the next major breakthrough.

Until then, follow me -- Sara Bellum -- through many other magazines in my series. We'll explore how drugs can affect the brain and also the nervous system.



Answers:  
(1) MYELIN  
(2) NEURON  
(3) HIPPOCAMPUS

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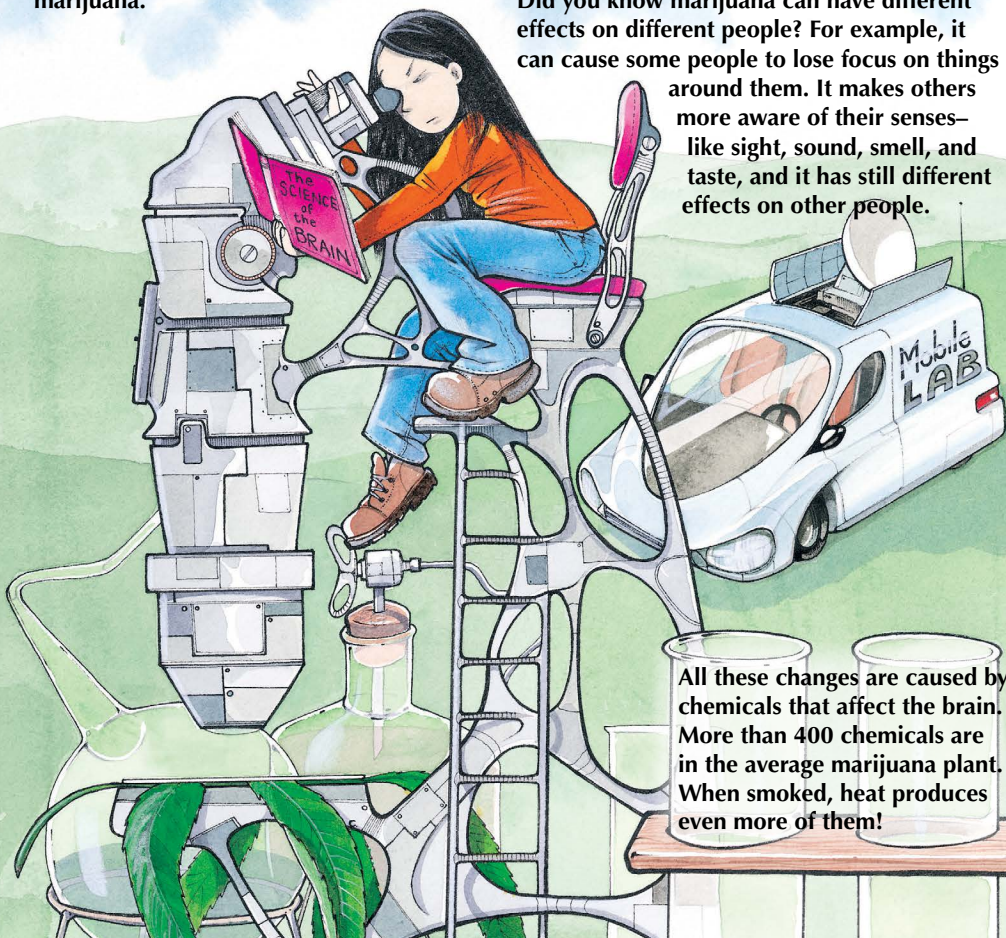


# The Brain's Response to Marijuana

Hi, my name is Sara Bellum. Welcome to my magazine series exploring the brain's response to drugs. In this issue, we'll investigate the fascinating facts about marijuana.

You may have heard it called weed, pot, grass, ganja or skunk, but marijuana by any other name is still a drug that affects the brain.

Did you know marijuana can have different effects on different people? For example, it can cause some people to lose focus on things around them. It makes others more aware of their senses—like sight, sound, smell, and taste, and it has still different effects on other people.



All these changes are caused by chemicals that affect the brain. More than 400 chemicals are in the average marijuana plant. When smoked, heat produces even more of them!

**National Institute on Drug Abuse**

## Where Does Marijuana Come From?

**Marijuana is the dried leaves and flowers of the hemp plant (*Cannabis sativa*). Like all plants it's sensitive to the environment where it grows.**

Different weather and soil conditions can change the amounts of the chemicals inside the plant. That means marijuana grown in a place like Hawaii might be chemically different than marijuana from Mexico, or vice-versa.

# Marijuana Invades the Brain

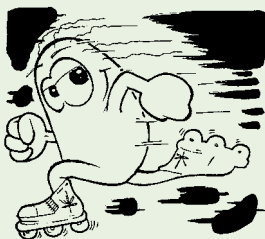
## How do the chemicals in marijuana change the way a person sees, hears, smells, tastes, and feels things?

When someone uses marijuana, these chemicals travel through the bloodstream and quickly attach to special places on the brain's nerve cells. These places are called receptors, because they receive information from other nerve cells. Chemicals carry this information, which changes the nerve cell receiving it.

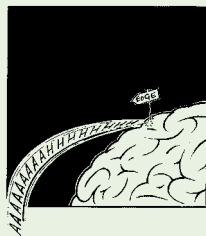
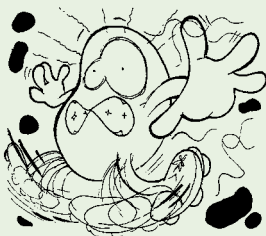
One chemical in marijuana that has a big impact on the brain is called THC—tetrahydrocannabinol. (Whew! Try saying that 10 times fast.) Scientists have found that some areas of the brain have a lot of THC receptors, while others have very few or none. These clues are helping researchers figure out exactly how THC works in the brain.

## How Does Marijuana Affect Nerve Cells in the Brain?

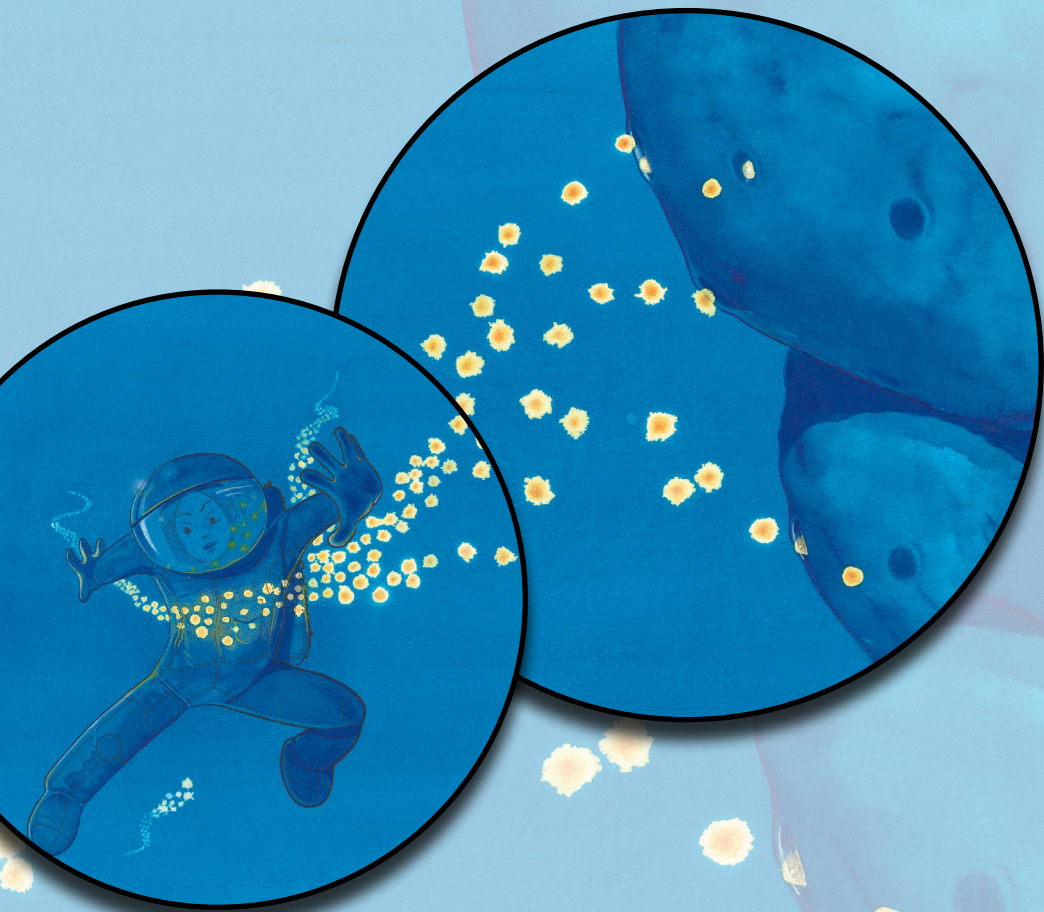
**Marijuana interferes with some parts of the brain—**



**such as those affecting emotions, memory  
and judgment—to lose balance and  
controooooooooooooooooooooooooooooo!!!!!!!!!!!!!!.**







## **Marijuana may cause some parts of the body to react in different ways. What do you know about:**

1. Rapid Heartbeat—up to how many beats per minute? Is it 100, 130, or 160?
2. Dilated blood vessels—can be seen in what part of the body? Is it the face, the eyes, the feet?
3. A feeling of panic—accompanied by what kind of sensations? Is it sweating, dry mouth, breathing difficulties, or all of these?
4. Daily cough and more frequent chest colds very much like who? Is it tobacco smokers, construction workers, or the elderly?

**Answers:**  
 1. Marijuana can speed the heart rate up to 160 beats per minute.  
 2. Dilated blood vessels make the whites of the eyes turn red.  
 3. Panic feelings may be accompanied by sweating, dry mouth and trouble breathing.  
 4. Tobacco smokers.



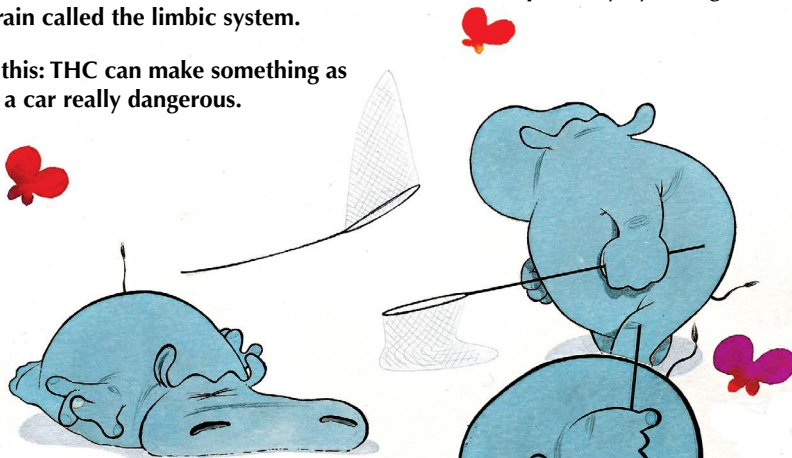
# Effects of Marijuana on the Brain

One region of the brain that contains a lot of THC receptors is the hippocampus, which usually helps with memory. When THC attaches to receptors in the hippocampus, it interferes with memory.

Researchers have also shown that heavy use of marijuana by young people can actually cause IQ to go down—and this change in IQ can last a long time and may even be permanent! This means that someone who uses marijuana may not do as well in school and may have trouble remembering things like their friend's phone number.

Maybe you've heard that marijuana can cause a range of emotions from uncontrollable laughter to paranoia. That's because THC also influences emotions, probably by acting on a region of the brain called the limbic system.

And don't forget this: THC can make something as simple as driving a car really dangerous.



## The Search Continues

Some chemicals in the marijuana plant might be useful in the world of medicine—like preventing nausea and blocking pain, and possibly treating other problems and diseases. The trick is for scientists to get these results without the harmful effects.

Researchers are studying these chemicals—so that they can develop medications that are chemically similar to THC but don't negatively affect the brain.



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National Institute  
on Drug Abuse



# The Brain's Response to Methamphetamine

Hi, my name's Sara Bellum. Welcome to my magazine series exploring the brain's response to drugs. In this issue, we'll investigate many fascinating facts about the stimulant drug methamphetamine. Some of this information was only recently discovered by leading scientists.

Speed, meth, chalk, crystal, ice, glass. These are all names for the drug methamphetamine. Methamphetamine comes in many different forms and is snorted, swallowed, injected, or smoked.

The smokable form is known as "ice" or "crystal," due to its appearance.

Methamphetamine is a powerful drug. It acts by changing how the brain works. It also speeds up many functions in the body. Methamphetamine has a chemical structure that is similar to another drug called amphetamine that I explore in my magazine on stimulants. Methamphetamine can cause lots of harmful things, including inability to sleep, paranoia, aggressiveness, and hallucinations. I'll tell you more about these later.



**National Institute on Drug Abuse**



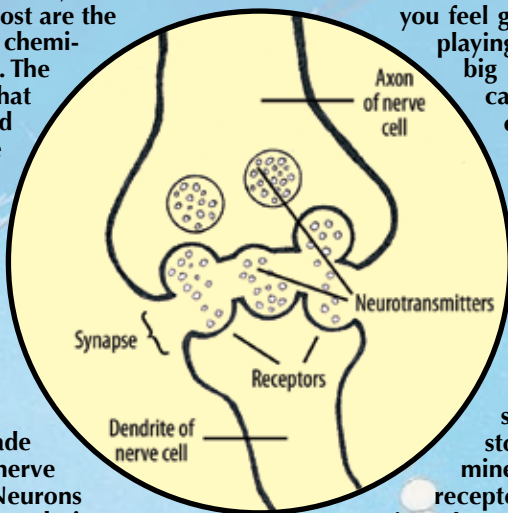
# How Does Methamphetamine Cause Its Effects?

No matter how methamphetamine is used, it eventually ends up in the bloodstream where it is circulated throughout the brain. Methamphetamine can affect lots of brain structures, but the ones it affects the most are the ones that contain a chemical called dopamine. The reason for this is that the shape, size, and chemical structure of methamphetamine and dopamine are similar. Before I tell you more about dopamine and methamphetamine, I'd better tell you how nerve cells work.

Your brain is made up of billions of nerve cells (or neurons). Neurons come in all shapes and sizes, but most have three important parts: a cell body that contains the nucleus and directs the activities of the neuron; dendrites, short fibers that receive messages from other neurons and relay them to the cell body; and an axon, a long single fiber that carries messages from the cell body to dendrites of other neurons.

Axons of one neuron and the dendrites of a neighboring neuron are located very close to each other, but they don't actually touch. Therefore, to communicate with each other they use chemical messengers known as neurotransmitters. When one neuron wants to send a message to another neuron it releases a neurotransmitter from its axon into the small space that separates the two neurons. This space is called a synapse. The neurotransmitter crosses the synapse and attaches to specific places on the dendrites of the neighboring neuron called receptors. Once the neurotransmitter has relayed its message, it is either destroyed or taken back up into the first neuron where it is recycled for use again.

There are many different neurotransmitters, but the one that is most affected by methamphetamine is dopamine. Dopamine is sometimes called the pleasure neurotransmitter because it helps you feel good from things like playing soccer, eating a big piece of chocolate cake, or riding a roller coaster. When something pleasurable happens, certain axons release lots of dopamine. The dopamine attaches to receptors on dendrites of neighboring neurons and passes on the pleasure message. This process is stopped when dopamine is released from the receptors and pumped back into the neuron that released it where it is stored for later use.



## Explo the Sy

# **Methamphetamine Changes the Brain**

Usually neurons recycle dopamine. But methamphetamine is able to fool neurons into taking it up just like they would dopamine. Once inside a neuron, methamphetamine causes that neuron to release lots of dopamine. All this dopamine causes the person to feel an extra sense of pleasure that can last all day.

But eventually these pleasurable effects stop. They are followed by unpleasant feelings called a "crash" that often lead a person to use more of the drug. If a person continues to use methamphetamine, they will have a difficult time feeling pleasure from anything. Imagine no longer enjoying your favorite food or an afternoon with your friends.

# **Methamphetamine Has Lots of Other Effects**

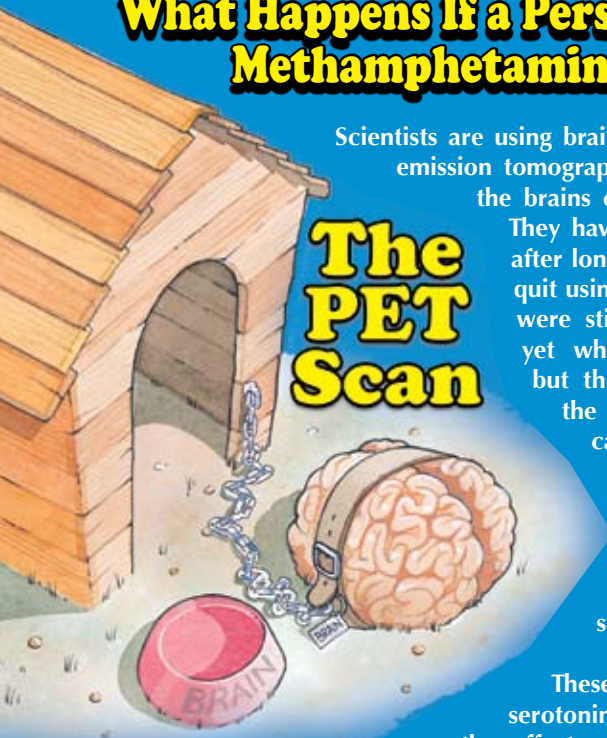
Because it is similar to dopamine, methamphetamine can change the function of any neuron that contains dopamine. And if this weren't enough, methamphetamine can also affect neurons that contain two other neurotransmitters called serotonin and norepinephrine. All of this means that methamphetamine can

change how lots of things in the brain and the body work. Even small amounts of methamphetamine can cause a person to be more awake and active, lose their appetite, and become irritable and aggressive. Methamphetamine also causes a person's blood pressure to increase and their heart to beat faster.





# What Happens If a Person Uses Methamphetamine for a Long Time?



## The PET Scan

Scientists are using brain imaging techniques, like positron emission tomography (called PET for short), to study the brains of human methamphetamine users. They have discovered that even three years after long-time methamphetamine users had quit using the drug, their dopamine neurons were still damaged. Scientists don't know yet whether this damage is permanent, but this research shows that changes in the brain from methamphetamine use can last a long time. Research with animals has shown that the drug methamphetamine can also damage neurons that contain serotonin. This damage also continues long after the drug use is stopped.

These changes in dopamine and serotonin neurons may explain some of the effects of methamphetamine. If a person uses methamphetamine for a long time, they may become paranoid. They may also hear and see things that aren't there. These are called hallucinations. Because methamphetamine causes big increases in blood pressure, someone using it for a long time may also have permanent damage to blood vessels in the brain. This can lead to strokes caused by bleeding in the brain.

## The Search Continues

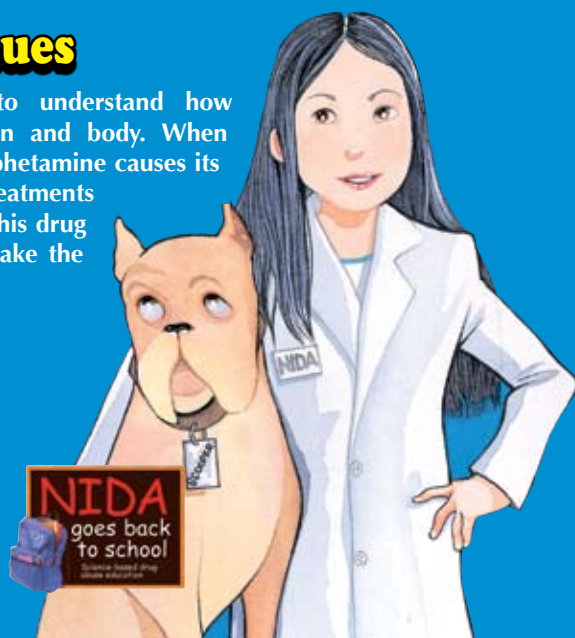
Researchers are only beginning to understand how methamphetamine acts in the brain and body. When they learn more about how methamphetamine causes its effects, they may be able to develop treatments that prevent or reverse the damage this drug can cause. Maybe someday you'll make the next major breakthrough.

**For more information, visit:**  
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# The Brain's Response to Nicotine

Hi, my name's Sara Bellum. Welcome to my magazine series exploring the brain's response to drugs. In this issue, we'll investigate the fascinating facts about nicotine. Some of this information was only recently discovered by leading scientists.

For centuries, people have chewed and smoked tobacco, which comes from the plant *nicotiana tabacum*. The reason tobacco is used by so many people is because it contains a powerful drug known as nicotine.

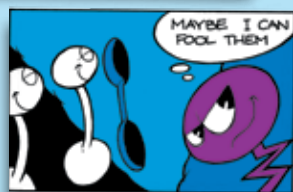
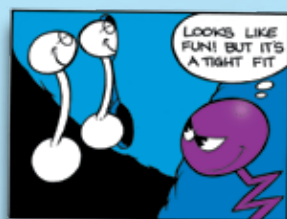
When tobacco is smoked, nicotine is absorbed by the lungs and quickly moved into the bloodstream, where it is circulated throughout the brain. All of this happens very rapidly. In fact, nicotine reaches the brain within 8 seconds after someone inhales tobacco smoke. Nicotine can also enter the bloodstream through the mucous membranes that line the mouth (if tobacco is chewed) or nose (if snuff is used), and even through the skin.

Nicotine affects the entire body. Nicotine acts directly on the heart to change heart rate and blood pressure. It also acts on the nerves that control respiration to change breathing patterns. In high concentrations, nicotine is deadly, in fact one drop of purified nicotine on the tongue will kill a person. It's so lethal that it has been used as a pesticide for centuries.

So why do people smoke? Because nicotine acts in the brain where it can stimulate feelings of pleasure.

**National Institute on Drug Abuse**





# How Does Nicotine Act in the Brain?

Your brain is made up of billions of nerve cells. They communicate by releasing chemical messengers called neurotransmitters. Each neurotransmitter is like a key that fits into a special “lock,” called a receptor, located on the surface of nerve cells. When a neurotransmitter finds its receptor, it activates the receptor’s nerve cell.

The nicotine molecule is shaped like a neurotransmitter called acetylcholine. Acetylcholine and its receptors are involved in many functions, including muscle movement, breathing, heart rate, learning, and memory. They also cause the release of other neurotransmitters and hormones that affect your mood, appetite, memory, and more. When nicotine gets into the brain, it attaches to acetylcholine receptors and mimics the actions of acetylcholine.

Nicotine also activates areas of the brain that are involved in producing feelings of pleasure and reward. Recently, scientists discovered that nicotine raises

the levels of a neurotransmitter called dopamine in the parts of the brain that produce feelings of pleasure and

reward. Dopamine, which is sometimes called the pleasure molecule, is the same neurotransmitter that is involved in addictions to other drugs such as cocaine and heroin. Researchers now believe that this change in dopamine may play a key role in all addictions. This may help explain why it is so hard for people to stop smoking.

## Easy to Start, Hard to Quit

Did you know that nicotine is as addictive as heroin or cocaine? If someone uses nicotine again and again, such as by smoking cigarettes or cigars or chewing tobacco, his or her body develops a tolerance for it. When someone develops tolerance, he or she needs more drug to get the same effect. Eventually, a person can become addicted. Once a person becomes addicted, it is extremely difficult to quit. People who start smoking before the age of 21 have the hardest time quitting, and fewer than 1 in 10 people who try to quit smoking succeed.

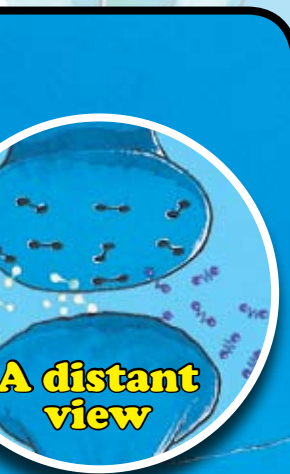
When nicotine addicts stop smoking they may suffer from restlessness, hunger, depression, headaches, and other uncomfortable feelings. These are called “withdrawal symptoms” because they happen when nicotine is withdrawn from the body.

## Got A Match?

The brain’s best defense against nicotine is to think hard before using it. Start by trying to match the correct percentages to the statements located below.

- |                                                                                                        |              |
|--------------------------------------------------------------------------------------------------------|--------------|
| 1. Percentage of smokers who start smoking in their teens.                                             | A. About 30% |
| 2. Percentage of smokers age 17 or under who say they regret starting.                                 | B. 80%-90%   |
| 3. Percentage of youth smokers who will continue smoking and die early from a smoking-related disease. | C. 70%       |

Answers:  
1. B-80%-90%  
2. C-70%  
3. A-About 30%



# America's Leading Preventable Killer

Withdrawal may be bad, but long-term smoking can be much worse. It raises your blood pressure, dulls your senses of smell and taste, reduces your stamina, and wrinkles your skin. More dangerously, long-term smoking can lead to fatal heart attacks, strokes, emphysema, and cancer.

You may be surprised to learn that tobacco use causes far more illnesses and death than all other addicting drugs combined. One out of every six deaths in the United States is a result of smoking.

But even when faced with risk of death, many people keep using tobacco because they are so addicted to nicotine. Believe it

or not, half of the smokers who have heart attacks keep smoking, even though their doctor warns them to stop. That's a strong addiction!

Smokeless tobacco also has harmful effects. Chewing tobacco can cause damage to gum tissue and even loss of teeth. It also reduces a person's ability to taste and smell. Most importantly, smokeless tobacco contains cancer-causing chemicals that can cause cancers of the mouth, pharynx, larynx, and esophagus. This can even happen in very young users of chewing tobacco. In fact, most people who develop these cancers were users of chewing tobacco.

## The Search Continues

The truth is, there's still a whole lot that scientists don't know about nicotine's effects on the brain. Maybe someday you'll make the next big discovery.

Until then, join me - Sara Bellum - in the other magazines in my series as we explore how drugs affect the brain and nervous system.

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AFFLICTION BOWL	
CHEWERS	SMOKERS
MOUTH CANCER	HEART ATTACK
PHARYNX CANCER	STROKE
LARYNX CANCER	EMPHYSEMA
ESOPHAGUS CANCER	CANCER
LOSS OF TEETH	







# The Brain's Response to Opioids

Hi, my name's Sara Bellum. Welcome to my magazine series exploring the brain's response to drugs. In this issue, we'll investigate the fascinating facts about opioids.

If you've ever seen *The Wizard of Oz*, then you've seen the poppy plant—the source of a type of drug called an opioid. When Dorothy lies down in a field of poppies, she falls into a deep sleep. No wonder the Latin name of this plant—*Papaver somniferum*—means “the poppy that makes you sleepy.”

Opioids can be made from opium, which comes from the poppy plant, or they can be made in a lab. Either way, they can

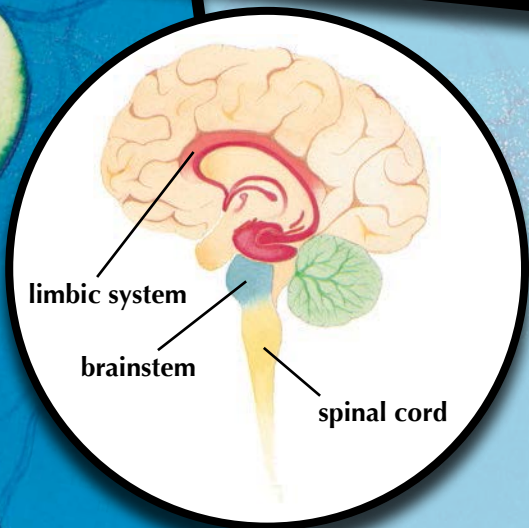
be helpful medicines—they are used as powerful painkillers, they are sometimes prescribed to control severe diarrhea, and they can also be found in cough medicine. Maybe you've heard of drugs called Vicodin, morphine, or codeine. These are examples of opioids. When used properly as medicine, they can be very helpful. But opioids used without a prescription, or taken in other ways or for different reasons than the doctor prescribed, can be dangerous and addictive.

Heroin is another example of an opioid, but it isn't used as a medicine—it's used to get high.



**National Institute on Drug Abuse**

# DEEP INSIDE THE BRAIN







## How Do Opioids Work?

Opioids look like chemicals in your brain and body that attach to tiny parts on nerve cells called opioid receptors. Scientists have found three types of opioid receptors: *mu*, *delta*, and *kappa* (named after letters in the Greek alphabet). Each of these receptors plays a different role. For example, *mu* receptors are responsible for opioids' pleasurable effects and their ability to relieve pain.

Opioids act on many places in the brain and nervous system, including:

- the **limbic system**, which controls emotions. Here, opioids can create feelings of pleasure, relaxation, and contentment.
- the **brainstem**, which controls things your body does automatically, like breathing. Here, opioids can slow breathing, stop coughing, and reduce feelings of pain.
- the **spinal cord**, which receives sensations from the body before sending them to the brain. Here too, opioids decrease feelings of pain, even after serious injuries.

Whether it is a medication like Vicodin or a street drug like heroin, the effects of opioids (and many other drugs) depend on how much you take and how you take them. If they are injected, they act faster and more intensely. If opioids are swallowed as pills, they take longer to reach the brain and are much safer.

## How Does Someone Become Addicted to Opioids?

Long-term opioid use changes the way nerve cells work in the brain. This happens even to people who take opioids for a long time to treat pain, as prescribed by their doctor. The nerve cells grow used to having opioids around, so that when they are taken away suddenly, the person can have lots of unpleasant feelings and reactions. These are known as withdrawal symptoms.

Have you ever had the flu? You probably had aching, fever, sweating, shaking, or chills. These are similar to withdrawal symptoms, but withdrawal symptoms are much worse.

That is why use of opioids should be carefully watched by a doctor—so that a person knows how much to take and when, as well as how to stop taking them to lessen the chances of withdrawal symptoms. Eventually, the cells will work normally again, but that takes time.

Someone who is addicted to opioids has other problems as well. For example, they keep taking the drug even though it may be having harmful effects on their life and their health. They have strong urges to take the drug—called cravings—and they no longer feel satisfied by natural rewards (like chocolate, TV, or a walk on the beach).



## Surprising Facts

Opioids can make you throw up—this can even happen to someone given opioids by a doctor—which is why many people don't like taking them.

Your brain makes its own versions of opioids, called endogenous opioids. These chemicals act just like opioid drugs, attaching to opioid receptors in your brain. Endogenous opioids help your body control pain. If you've ever felt pleasantly relaxed after exercising a lot, that feeling was probably caused by the release of these natural chemicals (sometimes called "endorphins") in your brain.

## The Search Continues

There is still a lot that scientists don't know about the effects of opioids on the brain. Maybe someday you will make the next big discovery!

Until then, join me—Sara Bellum—in the magazines in my series, as we explore how drugs affect the brain and nervous system.

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# **The Brain's Response to Prescription Drugs**

Hi! My name is Sara Bellum. Welcome to my magazine series that explores the brain's response to drugs. In this issue, we will investigate fascinating facts about prescription drugs.

Prescription drugs are medicines that are prescribed to a person by his or her doctor to treat diseases. Some prescription drugs affect the brain—especially those used to treat pain, or mental disorders such as anxiety or

attention-deficit hyperactivity disorder (ADHD).

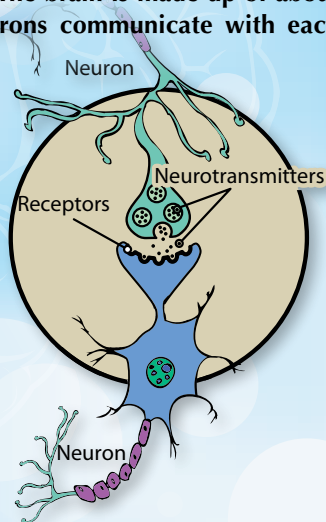
Doctors decide how much of a drug to give a person based on that person's age, size, and medical history. By doing so, doctors oversee the safe and proper use of prescription drugs. Abuse is when someone takes a prescription drug without a doctor's prescription or in a way or amount that is different from what was prescribed. Abuse of prescription drugs can have serious and harmful health effects, including poisoning and even death.



**National Institute on Drug Abuse**

# How Do Prescription Drugs Work in the Brain?

Prescription drugs change the chemistry of the brain. The brain is made up of about 100 billion neurons, also known as nerve cells. Neurons communicate with each other by using chemical messengers called neurotransmitters. There are many types of neurotransmitters, and each one carries a specific message. Neurotransmitters deliver their messages by attaching to special places on nerve cells called receptors. Prescription drugs act by mimicking certain neurotransmitters. Below, we will learn more about specific types of prescription drugs that can be dangerous when abused.



## Types of Prescription Drugs

### Prescription Painkillers

Prescription painkillers are powerful drugs that reduce pain. These drugs are very helpful to people with severe pain from injuries, and cancer and other diseases.

Prescription painkillers attach to particular sites in the brain called opioid receptors, which carry messages about pain. With proper use of prescription painkillers, the pain messages sent to the brain are changed and are no longer perceived as painful. Patients who are prescribed painkillers for a long period of time may develop a “physical dependence” on them. This is *not* the same as addiction. Physical dependence happens because the body adapts to having the drug around, and when its use is stopped abruptly, the person can experience symptoms of withdrawal. That is why these drugs are carefully monitored and should be taken or stopped only under a doctor’s orders.

Prescription painkillers can be highly addictive when used improperly—without a doctor’s prescription or in doses higher than prescribed. Addiction means that a person will strongly crave the drug and continue to use it despite severe consequences to their health and their life. Prescription painkillers also affect the brain areas controlling respiration, and when used improperly (or mixed with other drugs) can cause a severe decrease in breathing that can lead to death.

### Prescription Drugs for Sleep Disorders

Prescription drugs for sleep disorders increase levels of a neurotransmitter named gamma-aminobutyric acid (GABA). GABA sends messages that slow down bodily functions and make a person feel drowsy.

Prescription drugs for sleep disorders may have side effects, including headache, muscle aches, daytime sleepiness, trouble concentrating, and dizziness. Prescription drugs for sleep disorders should never be mixed with any other drugs that cause drowsiness, such as over-the-counter cold medicine, alcohol, or painkillers. If combined, they can slow a person’s heart rate and respiration, which can be fatal.

## Prescription Anti-anxiety Drugs

Doctors may prescribe drugs to help people with anxiety disorders. Some anti-anxiety drugs affect the neurotransmitter GABA.

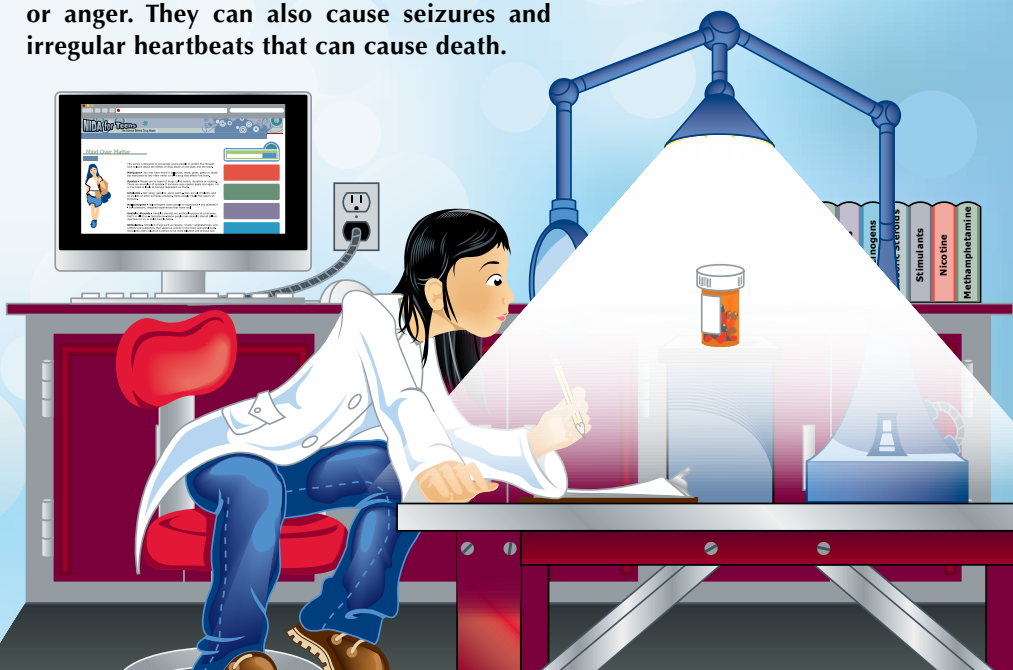
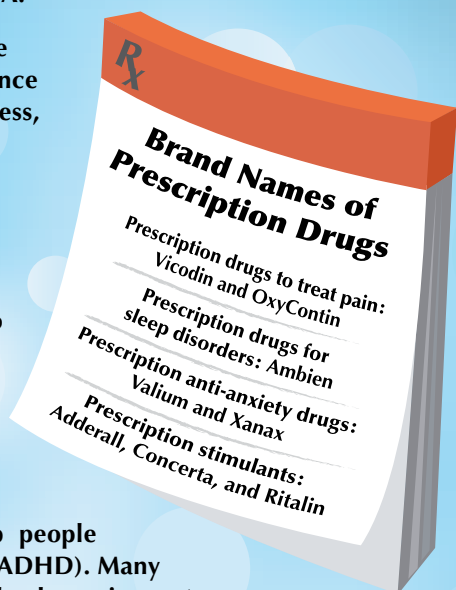
After taking anti-anxiety drugs for a long time and suddenly stopping, a person may experience withdrawal symptoms such as anxiety, shakiness, headache, dizziness, and, in extreme cases, seizures. Abusing prescription anti-anxiety drugs can result in addiction or overdose.

## Prescription Stimulants

Prescription stimulants cause neurons to release two neurotransmitters: dopamine and norepinephrine. Dopamine carries messages in the brain about feeling good. Norepinephrine is a chemical in the brain that helps people pay attention and focus.

Doctors often prescribe stimulants to help people with attention-deficit hyperactivity disorder (ADHD). Many scientists believe that in people with ADHD, the dopamine system works slightly differently than in people without the disorder. Prescription stimulants can bring brain dopamine function back to normal and help people with ADHD focus better and pay more attention.

Stimulants can be addictive and dangerous when abused. In fact, abusing stimulants can cause chest pain, stomachaches, and feelings of fear or anger. They can also cause seizures and irregular heartbeats that can cause death.





# Follow the Directions

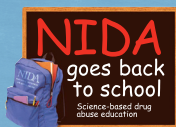
Prescription painkillers, drugs to treat sleep disorders, anti-anxiety drugs, and stimulants are powerful drugs. It is important to follow a doctor's, health care provider's, or pharmacist's instructions about how much to take and what things to avoid. For example, taking more than the prescribed amount of any prescription drug can lead to an overdose. People who overdose may vomit or even fall into a coma, depending on the drug. In addition, a person may have serious side effects from mixing prescription drugs with other medicines, over-the-counter drugs, or alcohol.

## Surprising Facts

- Prescription painkillers can cause nausea and vomiting.
- Mixing anti-anxiety or sleep disorder drugs with other drugs, particularly alcohol, can slow breathing, slow heart rate, and possibly lead to death.
- Abusing stimulants while taking a cold medicine with decongestants can cause dangerous increases in blood pressure and irregular heart rhythms.

## The Search Continues

There is much that scientists have yet to discover about the effects of prescription drugs on the brain and body. Maybe you will make the next big discovery! Until then, follow me—Sara Bellum—in the other magazines in my series, as we explore how drugs affect the brain and nervous system.



For more information, visit:  
[www.teens.drugabuse.gov](http://www.teens.drugabuse.gov)

To learn more about prescription drugs and other drugs of abuse, or to order materials on these topics, free of charge, in English or Spanish, visit the NIDA Web site at [www.drugabuse.gov](http://www.drugabuse.gov) or contact the DrugPubs Research Dissemination Center at 877-NIDA-NIH (877-643-2644; TTY/TDD: 240-645-0228).



## Anabolic Steroids in Medicine

Doctors never prescribe anabolic steroids for building muscle in young, healthy people. (Try push-ups instead!) But doctors sometimes prescribe anabolic steroids to treat some types of anemia or disorders in men that prevent the normal production of testosterone.

You may have heard that doctors sometimes prescribe steroids to reduce swelling. This is true, but these aren't anabolic steroids. They're corticosteroids.

Since corticosteroids don't build muscles the way that anabolic steroids do, people don't abuse them.

## STEROIDS

### True or False

- 1) Anabolic steroids can affect the hypothalamus.
- 2) Anabolic steroids strengthen the immune system.
- 3) Anabolic steroids can cause males' breasts to grow and females' breasts to shrink.

1) True, 2) False, 3) True.

## The Search Continues

There's still a whole lot that scientists don't know about the effects of anabolic steroids on the brain. Maybe someday you'll make the next big discovery.

Until then, join me—Sara Bellum—in the other magazines in my series, as we explore how drugs affect the brain and nervous system.



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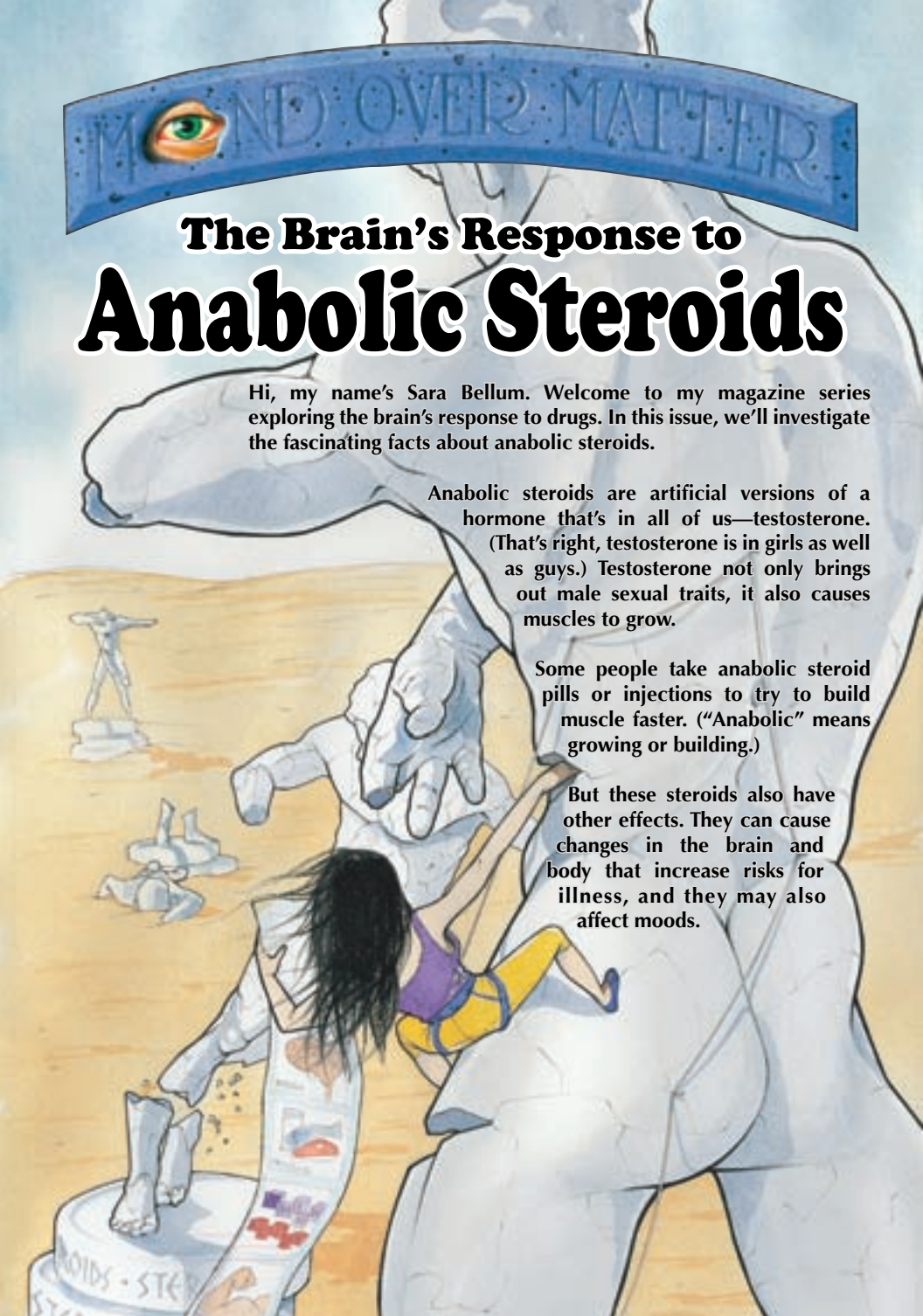
## The Brain's Response to Anabolic Steroids

Hi, my name's Sara Bellum. Welcome to my magazine series exploring the brain's response to drugs. In this issue, we'll investigate the fascinating facts about anabolic steroids.

Anabolic steroids are artificial versions of a hormone that's in all of us—testosterone. (That's right, testosterone is in girls as well as guys.) Testosterone not only brings out male sexual traits, it also causes muscles to grow.

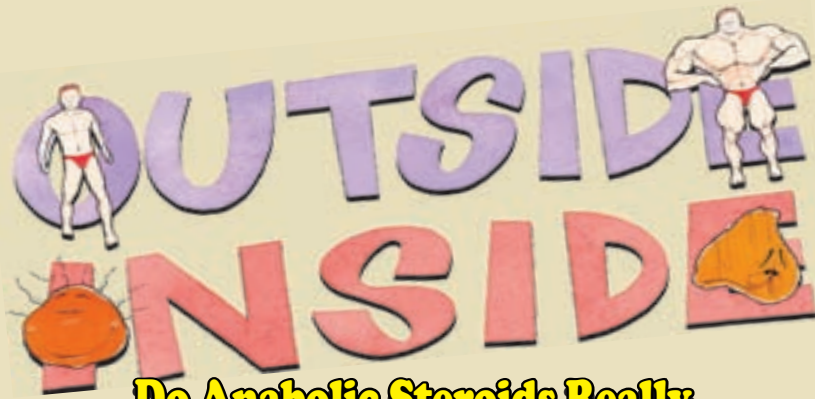
Some people take anabolic steroid pills or injections to try to build muscle faster. ("Anabolic" means growing or building.)

But these steroids also have other effects. They can cause changes in the brain and body that increase risks for illness, and they may also affect moods.



**National Institute on Drug Abuse**





## Do Anabolic Steroids Really Make the Body Stronger?

You may have heard that some athletes use anabolic steroids to gain size and strength. Maybe you've even seen an anabolic steroid user develop bigger muscles over time.

But while anabolic steroids can make some people look stronger on the outside, they may create weaknesses on the inside.

For example, anabolic steroids are bad for the heart—they can increase fat deposits in blood vessels, which can cause heart attacks and strokes. They may also damage the liver. Steroids can halt bone growth—which means that a teenage steroid user may not grow to his/her full adult height.

## Anabolic Steroids Affect the Brain

Scientists are still learning about how anabolic steroids affect the brain, and in turn, behavior. Research has shown that anabolic steroids may trigger aggressive behavior in some people. This means that someone who abuses anabolic steroids may act mean to people they're normally nice to, like friends and family, and they may even start fights. Some outbursts can

be so severe they have become known in the media as "roid rages." And when a steroid abuser stops using the drugs, they can become depressed, even suicidal. Researchers think that some of the changes in behavior may be caused by hormonal changes that are caused by steroids, but there is still a lot that is not known.

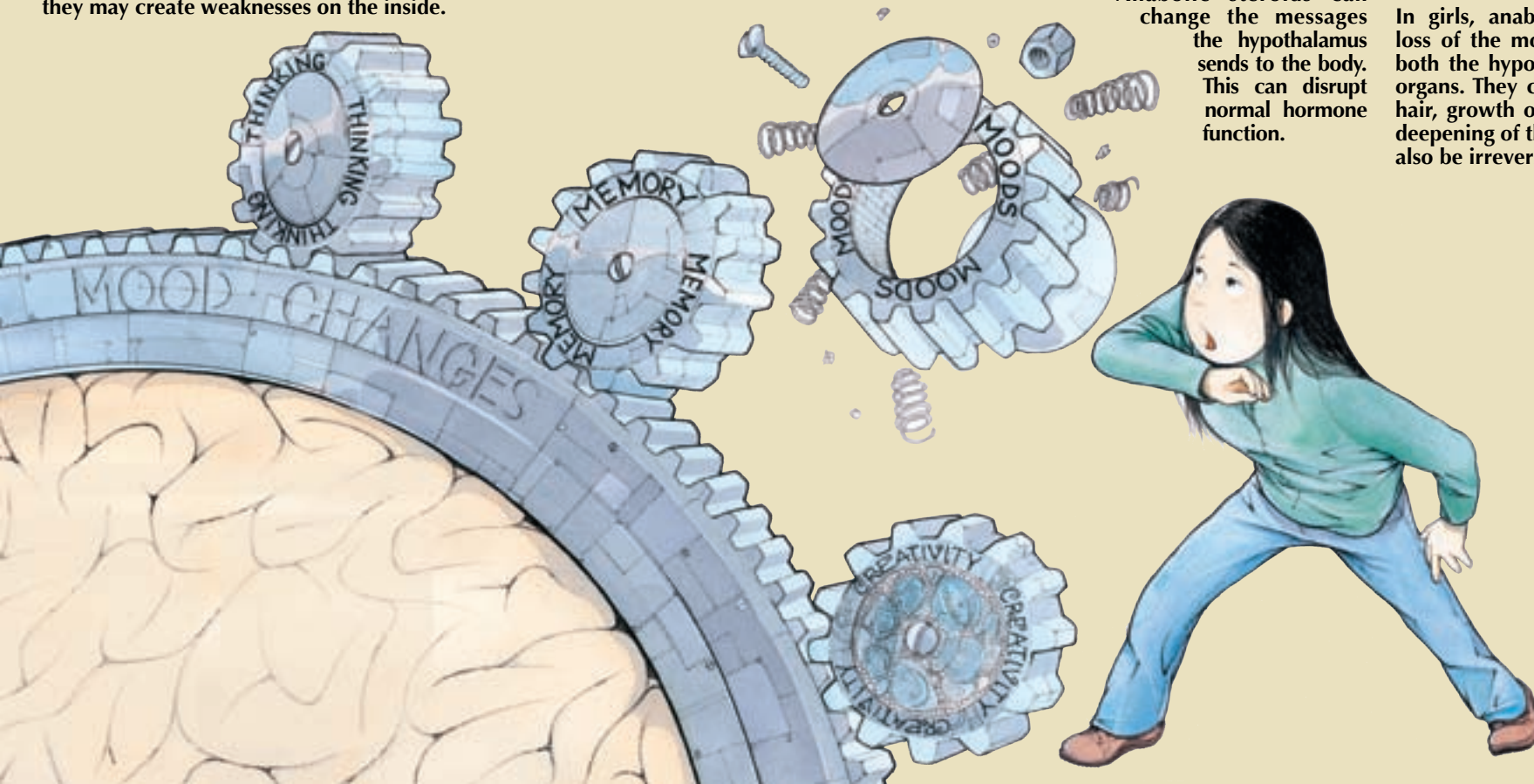
## Anabolic Steroids Can Confuse the Brain and Body

Your body's testosterone production is controlled by a group of nerve cells at the base of the brain, called the hypothalamus. The hypothalamus also does a lot of other things. It helps control appetite, blood pressure, moods, and reproductive ability.

In guys, anabolic steroids can interfere with the normal production of testosterone. They can also act directly on the testes and cause them to shrink. This can result in a lower sperm count. They can also cause an irreversible loss of scalp hair.

Anabolic steroids can change the messages the hypothalamus sends to the body. This can disrupt normal hormone function.

In girls, anabolic steroids can cause a loss of the monthly period by acting on both the hypothalamus and reproductive organs. They can also cause loss of scalp hair, growth of body and facial hair, and deepening of the voice. These changes can also be irreversible.





## Scientists Discover Answers

Fortunately, scientists have figured out how cocaine works, which will help them discover treatments for cocaine addiction. Right now there are talk therapies that can help, but someday there may be medications as well.

## The Search Continues

There's still a lot that scientists don't know about the effects of cocaine on the brain. Maybe someday you'll make the next big discovery. Until then, join me—Sara Bellum—in the other magazines in my series, as we explore how drugs affect the brain and nervous system.



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To learn more about cocaine and other drugs of abuse, or to order materials on these topics, free of charge, in English or Spanish, visit the NIDA Web site at **[www.drugabuse.gov](http://www.drugabuse.gov)** or contact the DrugPubs Research Dissemination Center at 877-NIDA-NIH (877-643-2644; TTY/TDD: 240-645-0228).

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## The Brain's Response to Cocaine

Hi, my name's Sara Bellum. Welcome to my magazine series exploring the brain's response to drugs. In this issue, we'll investigate the fascinating facts about the drug cocaine, which is considered a stimulant.

Have you eaten any chocolate or drunk any soda lately? If you have, there's a good chance you gave your body a dose of a stimulant—caffeine, which is also in coffee.

Eating or drinking a large amount of caffeine can make you feel jittery, nervous, or energetic. That's because caffeine—like any stimulant—changes the way your brain works.

But caffeine is just a mild example of a stimulant. Many other stimulant drugs are much stronger—and some are illegal and very dangerous.

Cocaine is made from the leaf of the coca plant. It often comes in the form of a white powder that some people inhale through their nose. Another form of cocaine, known as crack, can be smoked.



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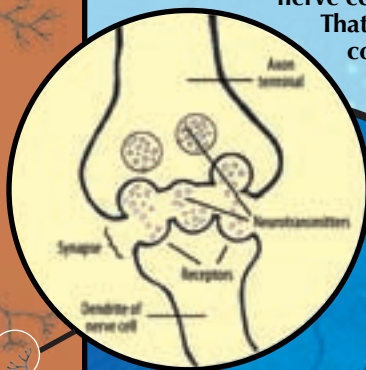
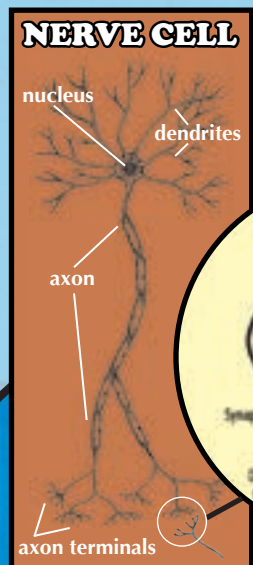
## Miscommunication in the Brain

Cocaine changes the way the brain works by changing the way nerve cells communicate. Nerve cells, called neurons, send messages to each other by releasing special chemicals called neurotransmitters. Neurotransmitters are able to work by attaching to key sites on neurons called receptors.

One of the neurotransmitters affected by cocaine is called dopamine. Dopamine is released by neurons in the limbic system—the part of the brain that controls feelings of pleasure.

Normally, once dopamine has attached to a nerve cell's receptor and caused a change in the cell, it's pumped back to the neuron that released it. But cocaine blocks the pump, called the dopamine transporter. Dopamine then builds up in the gap (synapse) between neurons.

The result: dopamine keeps affecting a nerve cell after it should have stopped. That's why someone who uses cocaine feels an extra sense of pleasure for a short time.



## Cocaine Can Change the Way the Brain Works

Although cocaine may make someone feel pleasure for a while, later it can take away a person's ability to feel pleasure from natural rewards, like a piece of chocolate or a good time with friends. Research suggests that long-term cocaine use may reduce the amount of dopamine or number of dopamine receptors in the brain. When this happens, nerve cells need

more dopamine to function normally—or more drug to be able to feel pleasure.

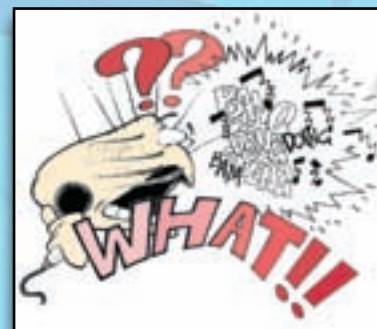
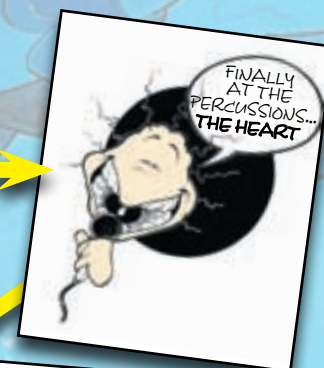
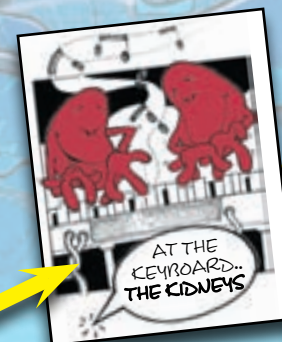
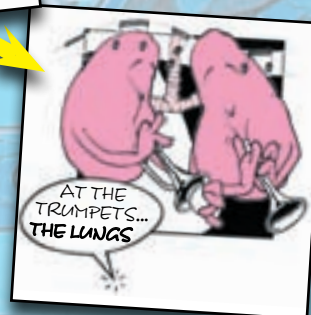
If a long-term user of cocaine stops taking the drug, the person feels tired and sad, and experiences strong craving for the drug. These feelings can last for a long time, until the brain (and the person) recovers from addiction.

## Cocaine Tightens Blood Vessels

Cocaine causes the body's blood vessels to become narrow, constricting the flow of blood. This is a problem. It forces the heart to work harder to pump blood through the body. (If you've ever tried squeezing into a tight pair of pants, then you know how hard it is for the heart to pump blood through narrowed blood vessels.)

When the heart works harder, it beats faster. It may work so hard that it temporarily loses its natural rhythm. This is called fibrillation, and it can be very dangerous because it stops the flow of blood through the body.

Many of cocaine's effects on the heart are actually caused by cocaine's impact on the brain—the body's control center.





Have your perceptions been  
**ALTERED?**

Hallucinogens can change the way you see things. The experience is a little like looking at the optical illusion below.

## The Search Continues

The truth is, there's still a whole lot that scientists don't know about the effects of hallucinogens on the brain. Maybe someday you'll make the next big discovery.

Until then, join me—Sara Bellum—in the other magazines in my series, as we explore how drugs affect the brain and nervous system.



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## The Brain's Response to Hallucinogens

Hi, my name's Sara Bellum. Welcome to my magazine series exploring the brain's response to drugs. In this issue, we'll investigate the fascinating facts about hallucinogens.

Hallucinogens cause people to experience—you guessed it—hallucinations, imagined experiences that seem real.

The word "hallucinate" comes from Latin words meaning "to wander in the mind." No wonder some people refer to hallucinating as "tripping."

The "trips" caused by hallucinogens can last for hours. Parts of these trips can feel really good, and other parts can feel really terrible.

Hallucinogens powerfully affect the brain, distorting the way

our five senses work and changing our impressions of time and space. When people use these drugs a lot they may have a hard time concentrating, communicating, or telling the difference between reality and illusion.



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## Where Do Hallucinogens Come From?

Some hallucinogens can be found in plants. Mescaline comes from a cactus called peyote. And certain mushrooms, also known as “magic” mushrooms, are hallucinogens.

But many hallucinogens are chemicals that don’t occur in nature. Some examples are:

- LSD, also called acid
- MDA, also called the “love drug,” related to the stimulant amphetamine
- MDMA, known as ecstasy, also related to amphetamine
- PCP, often called angel dust

## How Hallucinogens Affect Your Senses

Your brain controls all of your perceptions—the way you see, hear, smell, taste, and feel. How does your brain communicate with the rest of your body? Chemical messengers transmit information from nerve cell to nerve cell in the body and the brain. Messages are constantly being sent back and forth with amazing speed.

Your nerve cells are called neurons, and their chemical messengers are called neurotransmitters. When neurotransmitters attach to special places on nerve cells (called receptors), they cause changes in the nerve cells.

This communication system can be disrupted by chemicals like hallucinogens, and the results are changes in the way you sense the world around you.

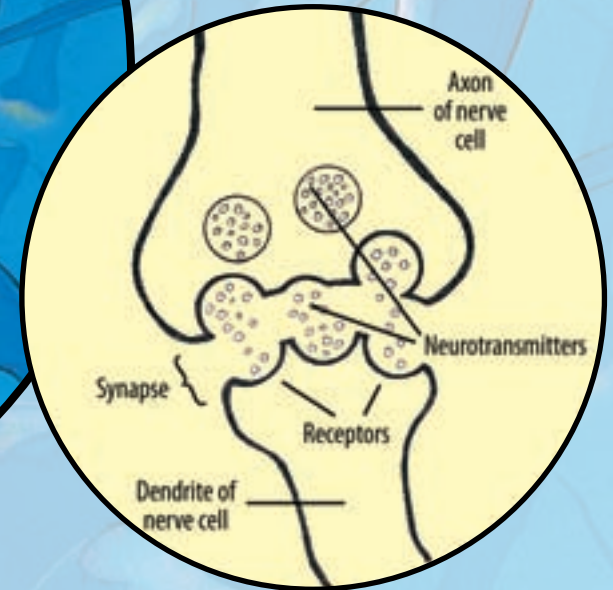
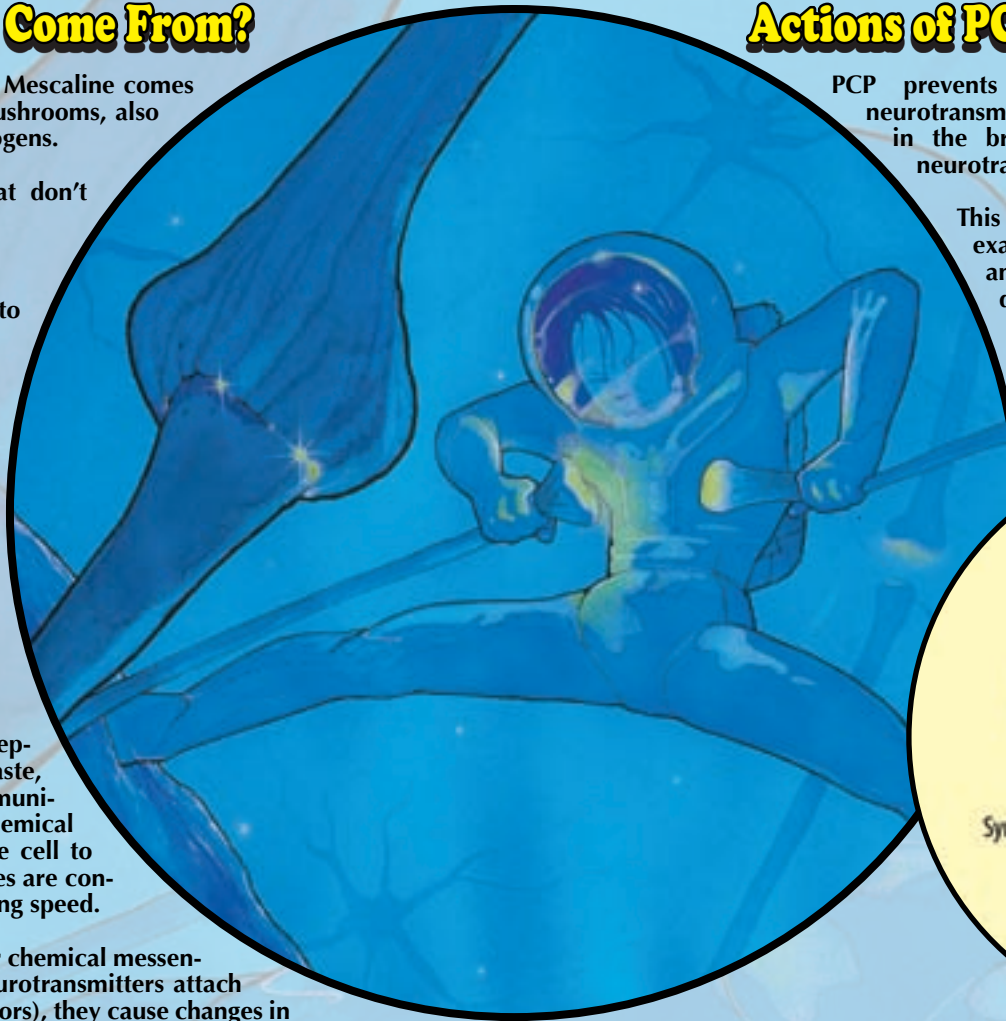
## How MDMA and MDA Affect Your Brain

MDMA and MDA cause neurons to release a neurotransmitter called serotonin, which can overactivate serotonin receptors. Serotonin is important to many types of nerve cells, including cells that receive sensory information and cells that control mood, sleep, and memory. Animal studies have taught us that MDMA and MDA can damage fibers from these nerve cells. And even though some of these fibers grow back, they don’t grow back normally. They can wind up in places where they don’t belong.

## Actions of PCP in the Brain

PCP prevents the actions normally caused when a neurotransmitter, called glutamate, attaches to its receptor in the brain. It also disrupts the actions of other neurotransmitters.

This drug’s effects are very unpredictable. For example, it may make some people hallucinate and become aggressive, while others may become drowsy and passive. It is also addictive.



## LSD: The Most Commonly Used Hallucinogen

LSD causes its effects mainly by activating one type of receptor for serotonin. Because serotonin has a role in many important functions, LSD use can have many effects. These may include sleeplessness, trembling, and raised heart rate and blood pressure.

LSD users may feel several emotions at once (including extreme terror), and their

senses may seem to get crossed—giving the feeling of hearing colors and seeing sounds.

Even a tiny speck of LSD can trigger these effects. And LSD has an unusual “echo”: many users have flashbacks—sudden repetitions of their LSD experiences—days or months after they stop using the drug.



## Changes in the Brain

Damage from long term use of inhalants can slow or stop nerve cell activity in some parts of the brain.

This might happen in the frontal cortex, the part of the brain that solves complex problems and plans ahead. Or if inhalants get into the brain's cerebellum, which controls movement and coordination, they can make someone move slowly or clumsily.

Studies show that neurons in a part of the brain called the hippocampus can also be damaged by inhalants. The damage occurs because the cells don't get enough oxygen.

Since the hippocampus helps control memory, someone who repeatedly uses inhalants may lose the ability to learn new things, may not recognize familiar things, or may have a hard time keeping track of simple conversations.

## Can You Fill the Gaps

Sometimes, nerve cells that are damaged by inhalants may be able to repair themselves. The empty spaces in the following brain-related words represent damaged neurons. See if you can "repair" them by filling in the blanks to complete the words. (Hint: All the words are in this magazine.)

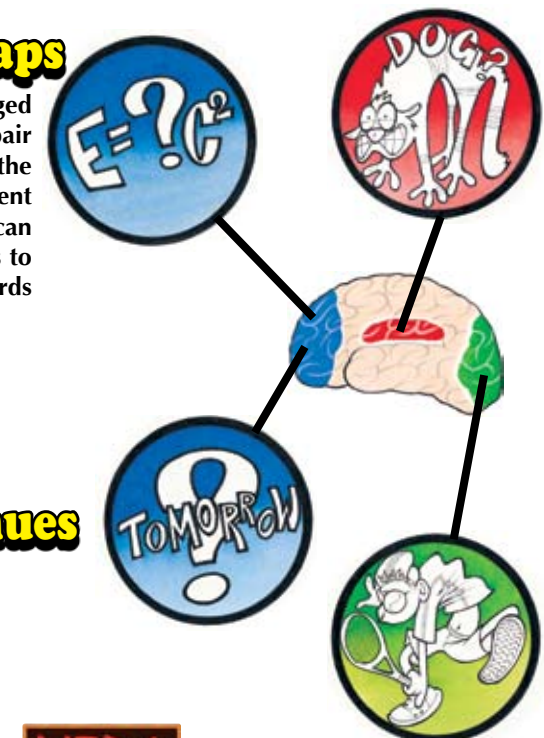
- 1) M . . L . .
- 2) . . U . O .
- 3) . . PP . . M . . S

## The Search Continues

The truth is, there's still a whole lot that scientists do not know about the effects of inhalants on the brain.

When scientists learn more about how various inhalants affect the brain, they may be able to develop treatments that prevent the damage inhalants can cause. Maybe someday you'll make the next major breakthrough.

Until then, follow me -- Sara Bellum -- through many other magazines in my series. We'll explore how drugs can affect the brain and also the nervous system.



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# MIND OVER MATTER

## The Brain's Response to Inhalants

Hi, my name's Sara Bellum. Welcome to my magazine series exploring the brain's response to drugs. In this issue, we'll investigate the fascinating facts about inhalants. Some of this information was only recently discovered by leading scientists.

Maybe you haven't heard of inhalants, but you probably come across them pretty often. Hair spray, gasoline, spray paint -- they are all inhalants, and so are lots of other everyday products.

Many inhalants have a strong smell. Some people inhale the vapors on purpose. That's why they're called "inhalants."

Why would anyone do this? Because the chemicals in these vapors can change the way the brain works, and those changes can make people feel very happy for a short time.

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## They Don't Go Away When You Exhale

Inhalant vapors often contain more than one chemical. Some leave the body quickly, but others are absorbed by fatty tissues in the brain and nervous system. They can stay there for a long time.

One of these fatty tissues is myelin -- a protective cover that surrounds many of the body's nerve cells (neurons). Nerve cells in your brain and spinal cord are sort of like "Command Central" for your body. They send and receive messages that control just about everything you think and do.

If you picture nerve cells as your body's electrical wiring, then think of myelin as the rubber insulation that protects an electrical cord.

One problem with inhalant use over the long term is that the chemicals can break down myelin. And if myelin breaks down, nerve cells may not be able to transmit messages.

## Beyond the Brain

One reason scientists are so interested in inhalants is that these chemicals affect the body in lots of ways. While some effects are due to changes in the brain, others are direct actions on other parts of the body, such as the circulatory system.

Did you know that some inhalants directly increase the size of blood vessels, allowing more blood to flow through? And some inhalants can make the heart beat faster. This can be a serious problem, especially if someone inhales butane gas.

Butane, found in cigarette lighters and refills, makes the heart extra sensitive to a chemical that carries messages from the

nervous system to the heart. This chemical, noradrenaline, tells the heart to beat faster when you're in a stressful situation -- like if something suddenly scares you.

If the heart becomes too sensitive to noradrenaline, a normal jolt of it may cause the heart to temporarily lose its rhythm and stop pumping blood through the body. Some inhalant users die this way. Inhalants can also cause death by suffocation. This occurs when the inhaled fumes take the place of oxygen in the lungs and the brain. This is known as Sudden Sniffing Death.



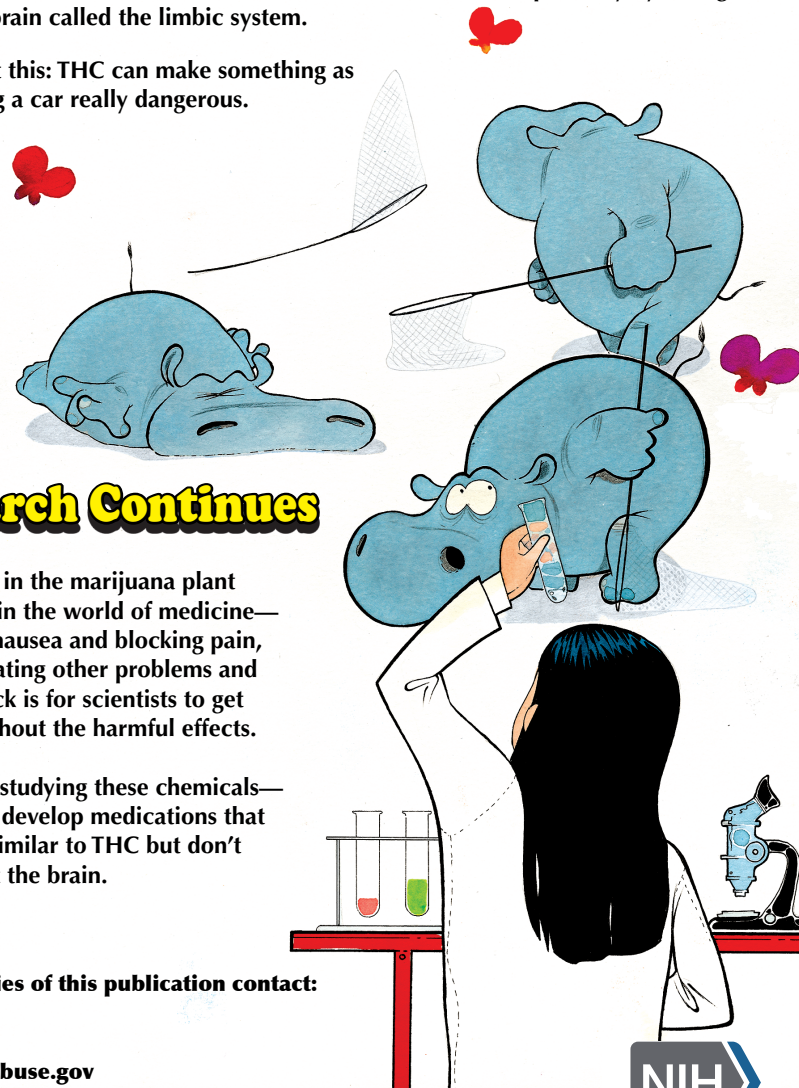
# Effects of Marijuana on the Brain

One region of the brain that contains a lot of THC receptors is the hippocampus, which usually helps with memory. When THC attaches to receptors in the hippocampus, it interferes with memory.

Researchers have also shown that heavy use of marijuana by young people can actually cause IQ to go down—and this change in IQ can last a long time and may even be permanent! This means that someone who uses marijuana may not do as well in school and may have trouble remembering things like their friend's phone number.

Maybe you've heard that marijuana can cause a range of emotions from uncontrollable laughter to paranoia. That's because THC also influences emotions, probably by acting on a region of the brain called the limbic system.

And don't forget this: THC can make something as simple as driving a car really dangerous.



## The Search Continues

Some chemicals in the marijuana plant might be useful in the world of medicine—like preventing nausea and blocking pain, and possibly treating other problems and diseases. The trick is for scientists to get these results without the harmful effects.

Researchers are studying these chemicals—so that they can develop medications that are chemically similar to THC but don't negatively affect the brain.

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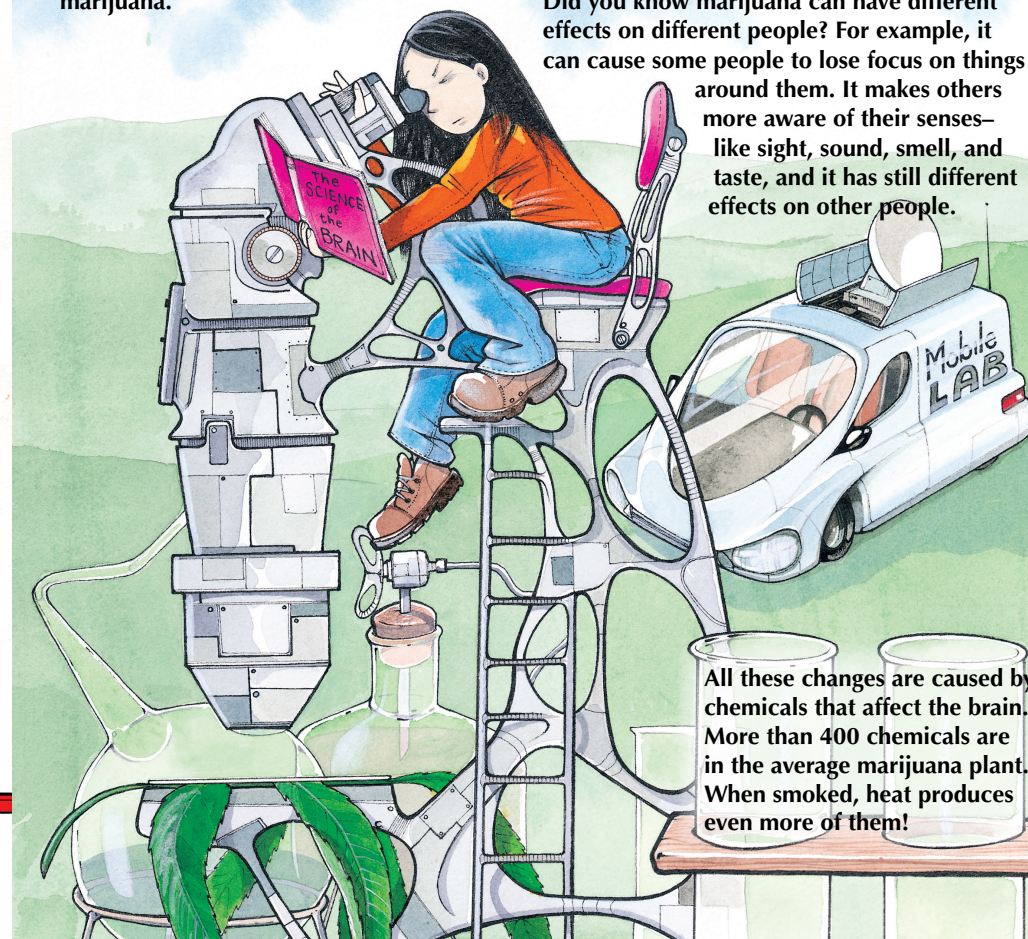


## The Brain's Response to Marijuana

Hi, my name is Sara Bellum. Welcome to my magazine series exploring the brain's response to drugs. In this issue, we'll investigate the fascinating facts about marijuana.

You may have heard it called weed, pot, grass, ganja or skunk, but marijuana by any other name is still a drug that affects the brain.

Did you know marijuana can have different effects on different people? For example, it can cause some people to lose focus on things around them. It makes others more aware of their senses—like sight, sound, smell, and taste, and it has still different effects on other people.



All these changes are caused by chemicals that affect the brain. More than 400 chemicals are in the average marijuana plant. When smoked, heat produces even more of them!

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## Where Does Marijuana Come From?

**Marijuana is the dried leaves and flowers of the hemp plant (*Cannabis sativa*). Like all plants it's sensitive to the environment where it grows.**

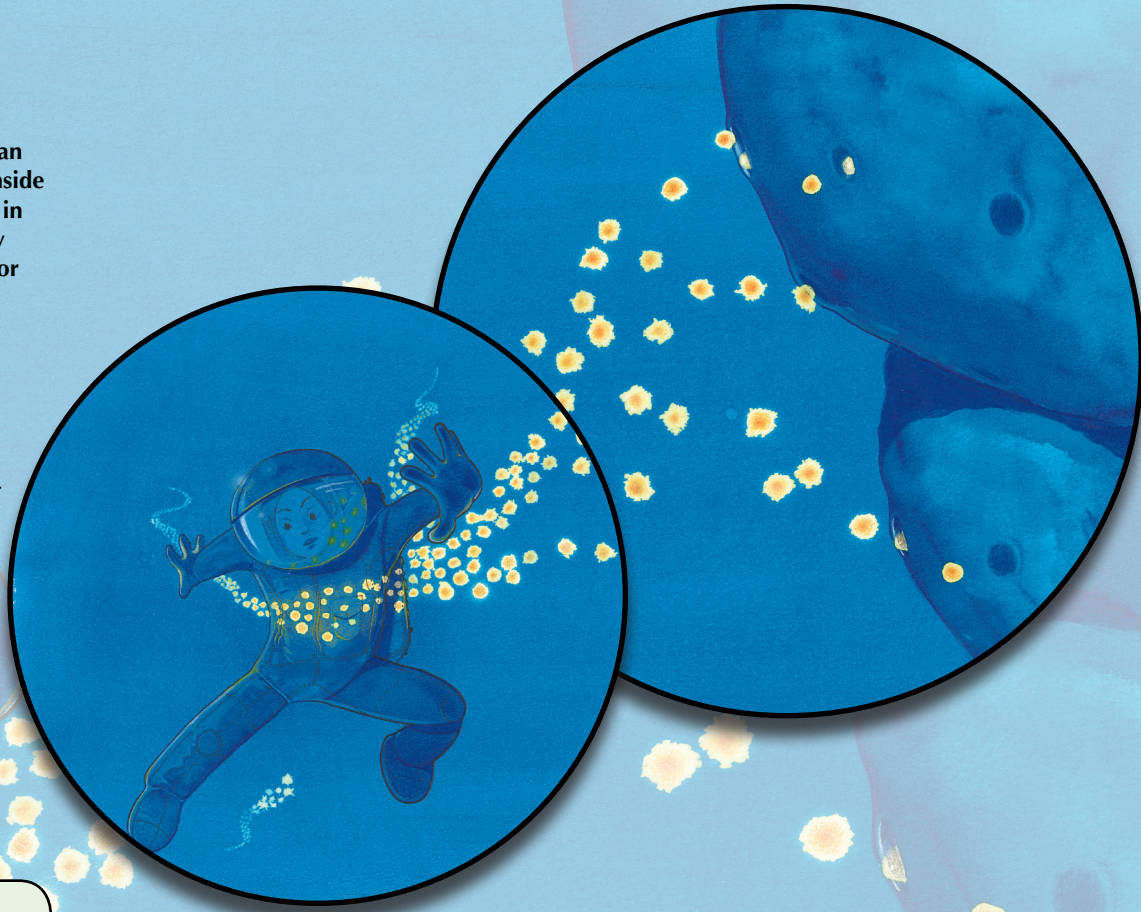
Different weather and soil conditions can change the amounts of the chemicals inside the plant. That means marijuana grown in a place like Hawaii might be chemically different than marijuana from Mexico, or vice-versa.

# Marijuana Invades the Brain

## How do the chemicals in marijuana change the way a person sees, hears, smells, tastes, and feels things?

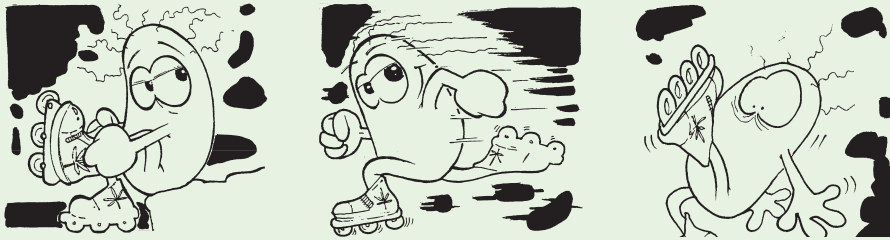
When someone uses marijuana, these chemicals travel through the bloodstream and quickly attach to special places on the brain's nerve cells. These places are called receptors, because they receive information from other nerve cells. Chemicals carry this information, which changes the nerve cell receiving it.

One chemical in marijuana that has a big impact on the brain is called THC—tetrahydrocannabinol. (Whew! Try saying that 10 times fast.) Scientists have found that some areas of the brain have a lot of THC receptors, while others have very few or none. These clues are helping researchers figure out exactly how THC works in the brain.

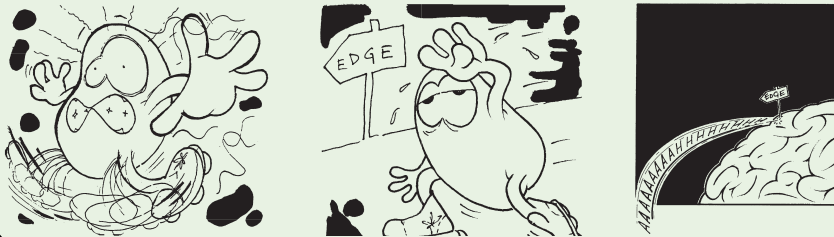


## How Does Marijuana Affect Nerve Cells in the Brain?

**Marijuana interferes with some parts of the brain—**



**such as those affecting emotions, memory  
and judgment—to lose balance and  
controooooooooooooooooooooooooooooo!!!!!!.**



**Marijuana may cause some parts of the body to react in different ways. What do you know about:**

1. Rapid Heartbeat—up to how many beats per minute? Is it 100, 130, or 160?
2. Dilated blood vessels—can be seen in what part of the body? Is it the face, the eyes, the feet?
3. A feeling of panic—accompanied by what kind of sensations? Is it sweating, dry mouth, breathing difficulties, or all of these?
4. Daily cough and more frequent chest colds very much like who? Is it tobacco smokers, construction workers, or the elderly?

**Answers:**

1. Marijuana can speed the heart rate up to 160 beats per minute.
2. Dilated blood vessels make the whites of the eyes turn red.
3. Panic feelings may be accompanied by sweating, dry mouth and trouble breathing.
4. Tobacco smokers.

**Answers:**



## What Happens If a Person Uses Methamphetamine for a Long Time?

### The PET Scan

Scientists are using brain imaging techniques, like positron emission tomography (called PET for short), to study the brains of human methamphetamine users. They have discovered that even three years after long-time methamphetamine users had quit using the drug, their dopamine neurons were still damaged. Scientists don't know yet whether this damage is permanent, but this research shows that changes in the brain from methamphetamine use can last a long time. Research with animals has shown that the drug methamphetamine can also damage neurons that contain serotonin. This damage also continues long after the drug use is stopped.

These changes in dopamine and serotonin neurons may explain some of the effects of methamphetamine. If a person uses methamphetamine for a long time, they may become paranoid. They may also hear and see things that aren't there. These are called hallucinations. Because methamphetamine causes big increases in blood pressure, someone using it for a long time may also have permanent damage to blood vessels in the brain. This can lead to strokes caused by bleeding in the brain.

### The Search Continues

Researchers are only beginning to understand how methamphetamine acts in the brain and body. When they learn more about how methamphetamine causes its effects, they may be able to develop treatments that prevent or reverse the damage this drug can cause. Maybe someday you'll make the next major breakthrough.

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## The Brain's Response to Methamphetamine

Hi, my name's Sara Bellum. Welcome to my magazine series exploring the brain's response to drugs. In this issue, we'll investigate many fascinating facts about the stimulant drug methamphetamine. Some of this information was only recently discovered by leading scientists.

Speed, meth, chalk, crystal, ice, glass. These are all names for the drug methamphetamine. Methamphetamine comes in many different forms and is snorted, swallowed, injected, or smoked.

The smokable form is known as "ice" or "crystal," due to its appearance.

Methamphetamine is a powerful drug. It acts by changing how the brain works. It also speeds up many functions in the body. Methamphetamine has a chemical structure that is similar to another drug called amphetamine that I explore in my magazine on stimulants. Methamphetamine can cause lots of harmful things, including inability to sleep, paranoia, aggressiveness, and hallucinations. I'll tell you more about these later.



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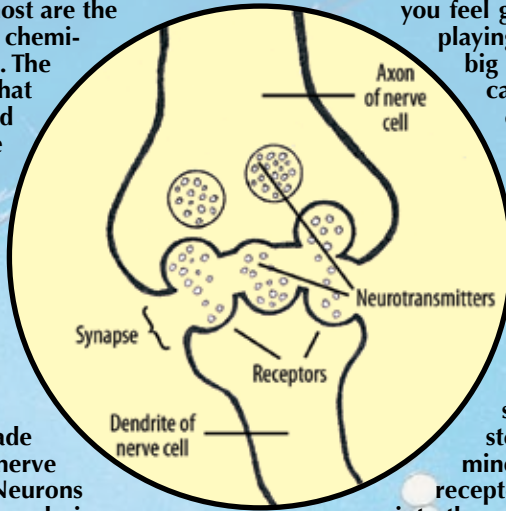


## How Does Methamphetamine Cause Its Effects?

No matter how methamphetamine is used, it eventually ends up in the bloodstream where it is circulated throughout the brain. Methamphetamine can affect lots of brain structures, but the ones it affects the most are the ones that contain a chemical called dopamine. The reason for this is that the shape, size, and chemical structure of methamphetamine and dopamine are similar. Before I tell you more about dopamine and methamphetamine, I'd better tell you how nerve cells work.

Your brain is made up of billions of nerve cells (or neurons). Neurons come in all shapes and sizes, but most have three important parts: a cell body that contains the nucleus and directs the activities of the neuron; dendrites, short fibers that receive messages from other neurons and relay them to the cell body; and an axon, a long single fiber that carries messages from the cell body to dendrites of other neurons.

Axons of one neuron and the dendrites of a neighboring neuron are located very close to each other, but they don't actually touch. Therefore, to communicate with each other they use chemical messengers known as neurotransmitters. When one neuron wants to send a message to another neuron it releases a neurotransmitter from its axon into the small space that separates the two neurons. This space is called a synapse. The neurotransmitter crosses the synapse and attaches to specific places on the dendrites of the neighboring neuron called receptors. Once the neurotransmitter has relayed its message, it is either destroyed or taken back up into the first neuron where it is recycled for use again.



There are many different neurotransmitters, but the one that is most affected by methamphetamine is dopamine. Dopamine is sometimes called the pleasure neurotransmitter because it helps you feel good from things like playing soccer, eating a big piece of chocolate cake, or riding a roller coaster. When something pleasurable happens, certain axons release lots of dopamine. The dopamine attaches to receptors on dendrites of neighboring neurons and passes on the pleasure message. This process is stopped when dopamine is released from the receptors and pumped back into the neuron that released it where it is stored for later use.

## Methamphetamine Changes the Brain

Usually neurons recycle dopamine. But methamphetamine is able to fool neurons into taking it up just like they would dopamine. Once inside a neuron, methamphetamine causes that neuron to release lots of dopamine. All this dopamine causes the person to feel an extra sense of pleasure that can last all day.

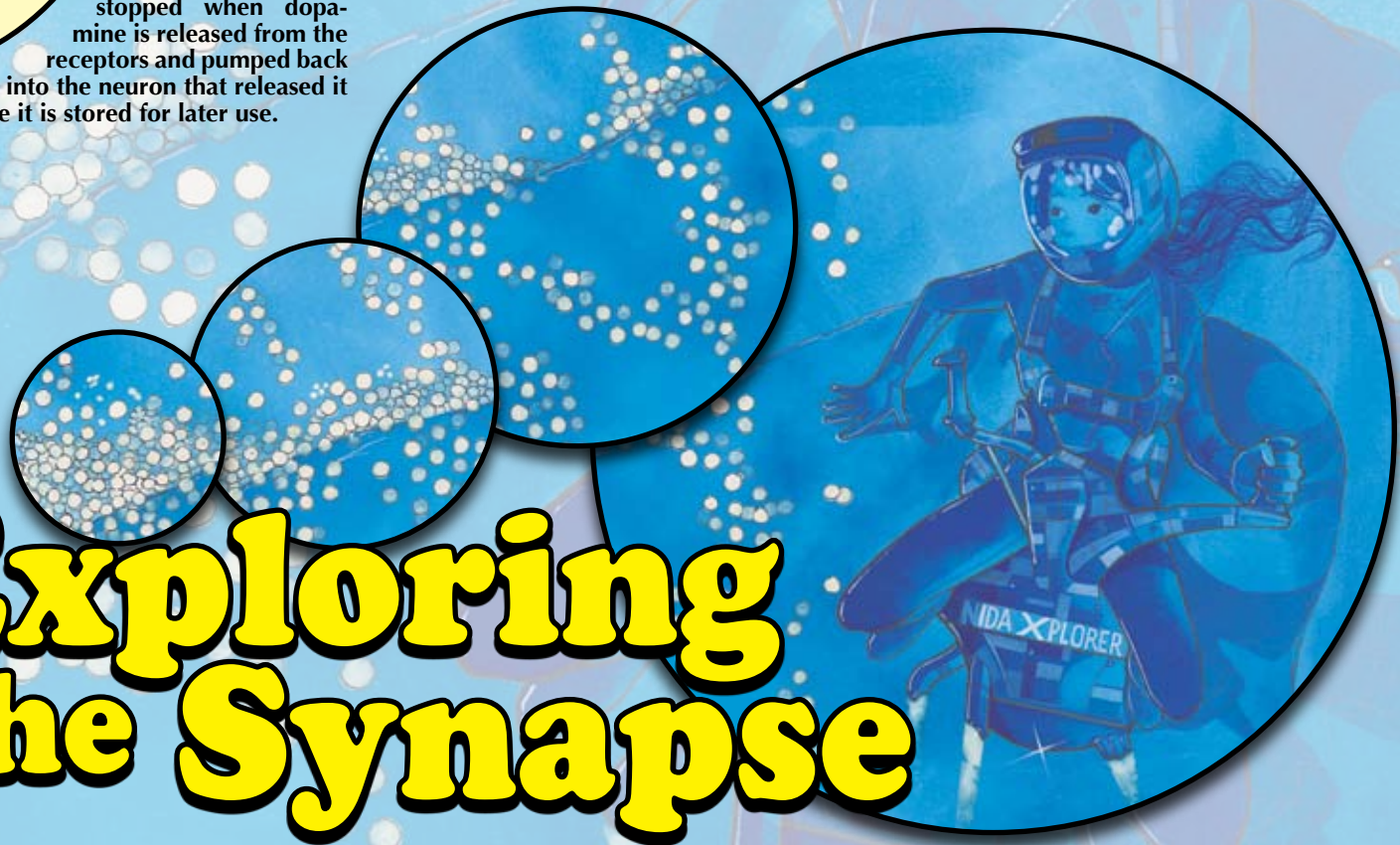
But eventually these pleasurable effects stop. They are followed by unpleasant feelings called a "crash" that often lead a person to use more of the drug. If a person continues to use methamphetamine, they will have a difficult time feeling pleasure from anything. Imagine no longer enjoying your favorite food or an afternoon with your friends.

## Methamphetamine Has Lots of Other Effects

Because it is similar to dopamine, methamphetamine can change the function of any neuron that contains dopamine. And if this weren't enough, methamphetamine can also affect neurons that contain two other neurotransmitters called serotonin and norepinephrine. All of this means that methamphetamine can

change how lots of things in the brain and the body work. Even small amounts of methamphetamine can cause a person to be more awake and active, lose their appetite, and become irritable and aggressive. Methamphetamine also causes a person's blood pressure to increase and their heart to beat faster.

# Exploring the Synapse





# America's Leading Preventable Killer

Withdrawal may be bad, but long-term smoking can be much worse. It raises your blood pressure, dulls your senses of smell and taste, reduces your stamina, and wrinkles your skin. More dangerously, long-term smoking can lead to fatal heart attacks, strokes, emphysema, and cancer.

You may be surprised to learn that tobacco use causes far more illnesses and death than all other addicting drugs combined. One out of every six deaths in the United States is a result of smoking.

But even when faced with risk of death, many people keep using tobacco because they are so addicted to nicotine. Believe it

or not, half of the smokers who have heart attacks keep smoking, even though their doctor warns them to stop. That's a strong addiction!

Smokeless tobacco also has harmful effects. Chewing tobacco can cause damage to gum tissue and even loss of teeth. It also reduces a person's ability to taste and smell. Most importantly, smokeless tobacco contains cancer-causing chemicals that can cause cancers of the mouth, pharynx, larynx, and esophagus. This can even happen in very young users of chewing tobacco. In fact, most people who develop these cancers were users of chewing tobacco.

## The Search Continues

The truth is, there's still a whole lot that scientists don't know about nicotine's effects on the brain. Maybe someday you'll make the next big discovery.

Until then, join me - Sara Bellum - in the other magazines in my series as we explore how drugs affect the brain and nervous system.

AFFLICTION BOWL	
CHEWERS	SMOKERS
MOUTH CANCER	HEART ATTACK
PHARYNX CANCER	STROKE
LARYNX CANCER	EMPHYSEMA
ESOPHAGUS CANCER	CANCER
LOSS OF TEETH	

THE CHEWERS  
WIN BY A FEW  
LOST TEETH...

For more information, visit:  
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## The Brain's Response to Nicotine

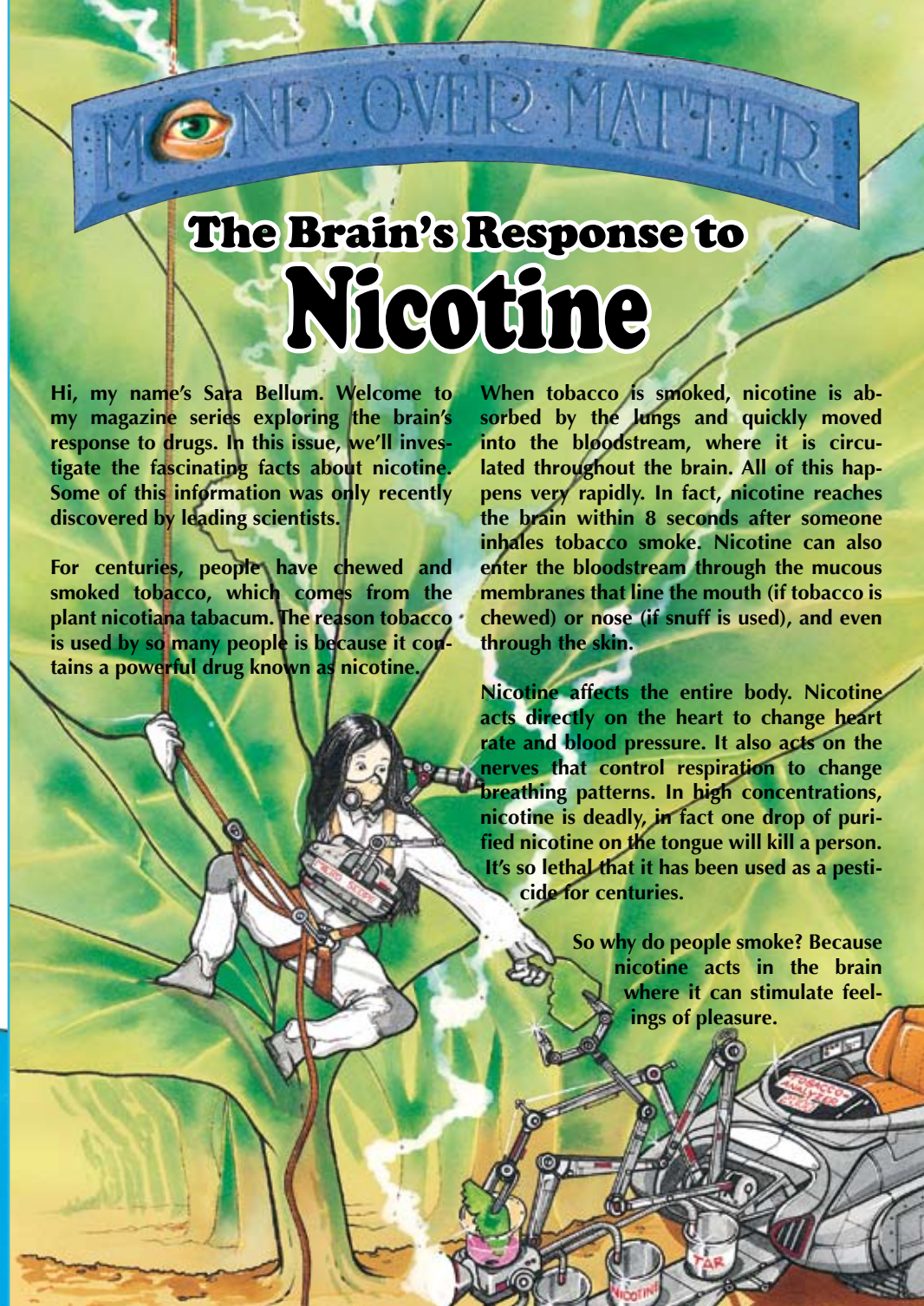
Hi, my name's Sara Bellum. Welcome to my magazine series exploring the brain's response to drugs. In this issue, we'll investigate the fascinating facts about nicotine. Some of this information was only recently discovered by leading scientists.

For centuries, people have chewed and smoked tobacco, which comes from the plant *nicotiana tabacum*. The reason tobacco is used by so many people is because it contains a powerful drug known as nicotine.

When tobacco is smoked, nicotine is absorbed by the lungs and quickly moved into the bloodstream, where it is circulated throughout the brain. All of this happens very rapidly. In fact, nicotine reaches the brain within 8 seconds after someone inhales tobacco smoke. Nicotine can also enter the bloodstream through the mucous membranes that line the mouth (if tobacco is chewed) or nose (if snuff is used), and even through the skin.

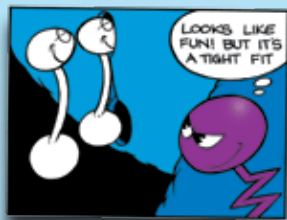
Nicotine affects the entire body. Nicotine acts directly on the heart to change heart rate and blood pressure. It also acts on the nerves that control respiration to change breathing patterns. In high concentrations, nicotine is deadly, in fact one drop of purified nicotine on the tongue will kill a person. It's so lethal that it has been used as a pesticide for centuries.

So why do people smoke? Because nicotine acts in the brain where it can stimulate feelings of pleasure.



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## How Does Nicotine Act in the Brain?

Your brain is made up of billions of nerve cells. They communicate by releasing chemical messengers called neurotransmitters. Each neurotransmitter is like a key that fits into a special "lock," called a receptor, located on the surface of nerve cells. When a neurotransmitter finds its receptor, it activates the receptor's nerve cell.

The nicotine molecule is shaped like a neurotransmitter called acetylcholine. Acetylcholine and its receptors are involved in many functions, including muscle movement, breathing, heart rate, learning, and memory. They also cause the release of other neurotransmitters and hormones that affect your mood, appetite, memory, and more. When nicotine gets into the brain, it attaches to acetylcholine receptors and mimics the actions of acetylcholine.

Nicotine also activates areas of the brain that are involved in producing feelings of pleasure and reward. Recently, scientists discovered that nicotine raises

the levels of a neurotransmitter called dopamine. Dopamine, which is sometimes called the pleasure molecule, is the same neurotransmitter that is involved in addictions to other drugs such as cocaine and heroin. Researchers now believe that this change in dopamine may play a key role in all addictions. This may help explain why it is so hard for people to stop smoking.

## Easy to Start, Hard to Quit

Did you know that nicotine is as addictive as heroin or cocaine? If someone uses nicotine again and again, such as by smoking cigarettes or cigars or chewing tobacco, his or her body develops a tolerance for it. When someone develops tolerance, he or she needs more drug to get the same effect. Eventually, a person can become addicted. Once a person becomes addicted, it is extremely difficult to quit. People who start smoking before the age of 21 have the hardest time quitting, and fewer than 1 in 10 people who try to quit smoking succeed.

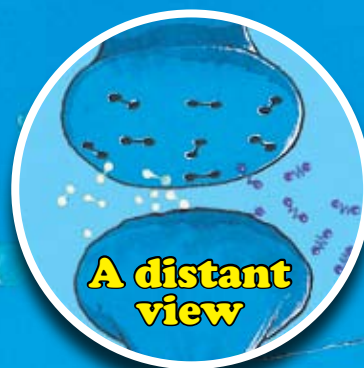
When nicotine addicts stop smoking they may suffer from restlessness, hunger, depression, headaches, and other uncomfortable feelings. These are called "withdrawal symptoms" because they happen when nicotine is withdrawn from the body.

## Got A Match?

The brain's best defense against nicotine is to think hard before using it. Start by trying to match the correct percentages to the statements located below.

- |                                                                                                        |              |
|--------------------------------------------------------------------------------------------------------|--------------|
| 1. Percentage of smokers who start smoking in their teens.                                             | A. About 30% |
| 2. Percentage of smokers age 17 or under who say they regret starting.                                 | B. 80%-90%   |
| 3. Percentage of youth smokers who will continue smoking and die early from a smoking-related disease. | C. 70%       |

Answers:  
1. B- 80%-90%  
2. C- 70%  
3. A- About 30%







## Surprising Facts

Opioids can make you throw up—this can even happen to someone given opioids by a doctor—which is why many people don't like taking them.

Your brain makes its own versions of opioids, called endogenous opioids. These chemicals act just like opioid drugs, attaching to opioid receptors in your brain. Endogenous opioids help your body control pain. If you've ever felt pleasantly relaxed after exercising a lot, that feeling was probably caused by the release of these natural chemicals (sometimes called "endorphins") in your brain.

## The Search Continues

There is still a lot that scientists don't know about the effects of opioids on the brain. Maybe someday you will make the next big discovery!

Until then, join me—Sara Bellum—in the magazines in my series, as we explore how drugs affect the brain and nervous system.

For printed copies of this publication contact:  
**NIDA DrugPubs**  
**1-877-643-2644**  
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# The Brain's Response to Opioids

Hi, my name's Sara Bellum. Welcome to my magazine series exploring the brain's response to drugs. In this issue, we'll investigate the fascinating facts about opioids.

If you've ever seen *The Wizard of Oz*, then you've seen the poppy plant—the source of a type of drug called an opioid. When Dorothy lies down in a field of poppies, she falls into a deep sleep. No wonder the Latin name of this plant—*Papaver somniferum*—means “the poppy that makes you sleepy.”

Opioids can be made from opium, which comes from the poppy plant, or they can be made in a lab. Either way, they can

be helpful medicines—they are used as powerful painkillers, they are sometimes prescribed to control severe diarrhea, and they can also be found in cough medicine. Maybe you've heard of drugs called Vicodin, morphine, or codeine. These are examples of opioids. When used properly as medicine, they can be very helpful. But opioids used without a prescription, or taken in other ways or for different reasons than the doctor prescribed, can be dangerous and addictive.

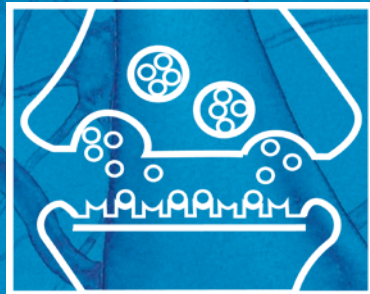
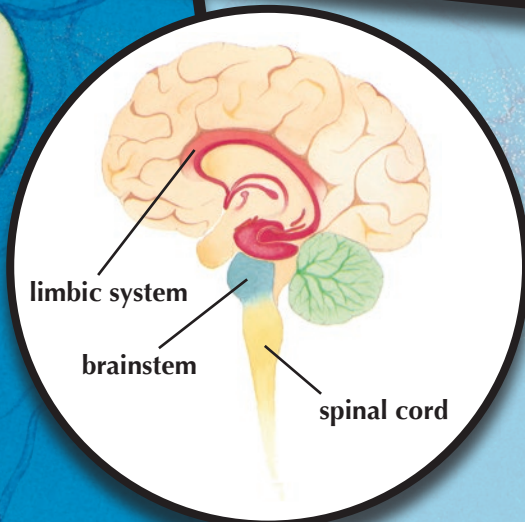
Heroin is another example of an opioid, but it isn't used as a medicine—it's used to get high.



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## DEEP INSIDE THE BRAIN



## How Do Opioids Work?

Opioids look like chemicals in your brain and body that attach to tiny parts on nerve cells called opioid receptors. Scientists have found three types of opioid receptors: *mu*, *delta*, and *kappa* (named after letters in the Greek alphabet). Each of these receptors plays a different role. For example, *mu* receptors are responsible for opioids' pleasurable effects and their ability to relieve pain.

Opioids act on many places in the brain and nervous system, including:

- the **limbic system**, which controls emotions. Here, opioids can create feelings of pleasure, relaxation, and contentment.
- the **brainstem**, which controls things your body does automatically, like breathing. Here, opioids can slow breathing, stop coughing, and reduce feelings of pain.
- the **spinal cord**, which receives sensations from the body before sending them to the brain. Here too, opioids decrease feelings of pain, even after serious injuries.

Whether it is a medication like Vicodin or a street drug like heroin, the effects of opioids (and many other drugs) depend on how much you take and how you take them. If they are injected, they act faster and more intensely. If opioids are swallowed as pills, they take longer to reach the brain and are much safer.

## How Does Someone Become Addicted to Opioids?

Long-term opioid use changes the way nerve cells work in the brain. This happens even to people who take opioids for a long time to treat pain, as prescribed by their doctor. The nerve cells grow used to having opioids around, so that when they are taken away suddenly, the person can have lots of unpleasant feelings and reactions. These are known as withdrawal symptoms.

Have you ever had the flu? You probably had aching, fever, sweating, shaking, or chills. These are similar to withdrawal symptoms, but withdrawal symptoms are much worse.

That is why use of opioids should be carefully watched by a doctor—so that a person knows how much to take and when, as well as how to stop taking them to lessen the chances of withdrawal symptoms. Eventually, the cells will work normally again, but that takes time.

Someone who is addicted to opioids has other problems as well. For example, they keep taking the drug even though it may be having harmful effects on their life and their health. They have strong urges to take the drug—called cravings—and they no longer feel satisfied by natural rewards (like chocolate, TV, or a walk on the beach).



## Follow the Directions

Prescription painkillers, drugs to treat sleep disorders, anti-anxiety drugs, and stimulants are powerful drugs. It is important to follow a doctor's, health care provider's, or pharmacist's instructions about how much to take and what things to avoid. For example, taking more than the prescribed amount of any prescription drug can lead to an overdose. People who overdose may vomit or even fall into a coma, depending on the drug. In addition, a person may have serious side effects from mixing prescription drugs with other medicines, over-the-counter drugs, or alcohol.

## Surprising Facts

- Prescription painkillers can cause nausea and vomiting.
- Mixing anti-anxiety or sleep disorder drugs with other drugs, particularly alcohol, can slow breathing, slow heart rate, and possibly lead to death.
- Abusing stimulants while taking a cold medicine with decongestants can cause dangerous increases in blood pressure and irregular heart rhythms.



## The Search Continues

There is much that scientists have yet to discover about the effects of prescription drugs on the brain and body. Maybe you will make the next big discovery! Until then, follow me—Sara Bellum—in the other magazines in my series, as we explore how drugs affect the brain and nervous system.



For more information, visit:  
[www.teens.drugabuse.gov](http://www.teens.drugabuse.gov)

To learn more about prescription drugs and other drugs of abuse, or to order materials on these topics, free of charge, in English or Spanish, visit the NIDA Web site at [www.drugabuse.gov](http://www.drugabuse.gov) or contact the DrugPubs Research Dissemination Center at 877-NIDA-NIH (877-643-2644; TTY/TDD: 240-645-0228).

# MIND OVER MATTER

## The Brain's Response to Prescription Drugs

Hi! My name is Sara Bellum. Welcome to my magazine series that explores the brain's response to drugs. In this issue, we will investigate fascinating facts about prescription drugs.

Prescription drugs are medicines that are prescribed to a person by his or her doctor to treat diseases. Some prescription drugs affect the brain—especially those used to treat pain, or mental disorders such as anxiety or

attention-deficit hyperactivity disorder (ADHD).

Doctors decide how much of a drug to give a person based on that person's age, size, and medical history. By doing so, doctors oversee the safe and proper use of prescription drugs. Abuse is when someone takes a prescription drug without a doctor's prescription or in a way or amount that is different from what was prescribed. Abuse of prescription drugs can have serious and harmful health effects, including poisoning and even death.

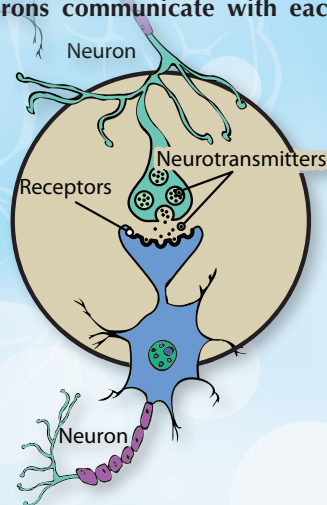


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# How Do Prescription Drugs Work in the Brain?

Prescription drugs change the chemistry of the brain. The brain is made up of about 100 billion neurons, also known as nerve cells. Neurons communicate with each other by using chemical messengers called neurotransmitters. There are many types of neurotransmitters, and each one carries a specific message. Neurotransmitters deliver their messages by attaching to special places on nerve cells called receptors. Prescription drugs act by mimicking certain neurotransmitters. Below, we will learn more about specific types of prescription drugs that can be dangerous when abused.



## Types of Prescription Drugs

### Prescription Painkillers

Prescription painkillers are powerful drugs that reduce pain. These drugs are very helpful to people with severe pain from injuries, and cancer and other diseases.

Prescription painkillers attach to particular sites in the brain called opioid receptors, which carry messages about pain. With proper use of prescription painkillers, the pain messages sent to the brain are changed and are no longer perceived as painful. Patients who are prescribed painkillers for a long period of time may develop a “physical dependence” on them. This is *not* the same as addiction. Physical dependence happens because the body adapts to having the drug around, and when its use is stopped abruptly, the person can experience symptoms of withdrawal. That is why these drugs are carefully monitored and should be taken or stopped only under a doctor’s orders.

Prescription painkillers can be highly addictive when used improperly—without a doctor’s prescription or in doses higher than prescribed. Addiction means that a person will strongly crave the drug and continue to use it despite severe consequences to their health and their life. Prescription painkillers also affect the brain areas controlling respiration, and when used improperly (or mixed with other drugs) can cause a severe decrease in breathing that can lead to death.

### Prescription Drugs for Sleep Disorders

Prescription drugs for sleep disorders increase levels of a neurotransmitter named gamma-aminobutyric acid (GABA). GABA sends messages that slow down bodily functions and make a person feel drowsy.

Prescription drugs for sleep disorders may have side effects, including headache, muscle aches, daytime sleepiness, trouble concentrating, and dizziness. Prescription drugs for sleep disorders should never be mixed with any other drugs that cause drowsiness, such as over-the-counter cold medicine, alcohol, or painkillers. If combined, they can slow a person’s heart rate and respiration, which can be fatal.

## Prescription Anti-anxiety Drugs

Doctors may prescribe drugs to help people with anxiety disorders. Some anti-anxiety drugs affect the neurotransmitter GABA.

After taking anti-anxiety drugs for a long time and suddenly stopping, a person may experience withdrawal symptoms such as anxiety, shakiness, headache, dizziness, and, in extreme cases, seizures. Abusing prescription anti-anxiety drugs can result in addiction or overdose.

### Prescription Stimulants

Prescription stimulants cause neurons to release two neurotransmitters: dopamine and norepinephrine. Dopamine carries messages in the brain about feeling good. Norepinephrine is a chemical in the brain that helps people pay attention and focus.

Doctors often prescribe stimulants to help people with attention-deficit hyperactivity disorder (ADHD). Many scientists believe that in people with ADHD, the dopamine system works slightly differently than in people without the disorder. Prescription stimulants can bring brain dopamine function back to normal and help people with ADHD focus better and pay more attention.

Stimulants can be addictive and dangerous when abused. In fact, abusing stimulants can cause chest pain, stomachaches, and feelings of fear or anger. They can also cause seizures and irregular heartbeats that can cause death.

